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BRISKET DISEASE

(Dropsy of High Altitudes)

By

Geo. H. Glover and I. E. Newsom

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BRISKET DISEASE

(Dropsy of High Altitudes.)

Preliminary Report.

INTRODUCTION.

For a number of years the Station has received letters from stockmen, living in the mountainous region of Colorado, giving accounts of a disease in cattle in which the most prominent symptom seemed to be a swelling of the brisket. Outside of a few visits made by the Veterinarian of the Experiment Station and the State Veterinarian, nothing of importance was done to determine the nature of the malady. In April, 1913, two South Park stockmen, Lew W. Robbins and David Collard, advanced one hundred dollars each, to be placed at the disposal of the Station for a study of the disease. Upon explanation of their action, the Park County Stockgrowers Association, which is composed of members who live at elevations of from eight to ten thousand feet, agreed to take over the expense and the two men were reimbursed. This money has been used only for work done in South Park and to meet incidental and traveling expenses. The Station has at all times paid the salaries of the men engaged in the work and furnished practically all of the necessary equipment. Since that time the State of Colorado has by special appropriation added materially to the fund thus broadening the scope of the work.

The work is still in progress and much of the detail is purposely left out of this report to be embodied in a later and more technical treatise on the subject, the idea being to give in a later report a rather complete and exhaustive description since to our knowledge the disease, as such, has not been described.

The plan of procedure mapped out was, first, to determine whether the disease could be transmitted from one animal to another; second, to find the cause; third, to make a complete study of its various manifestations; and fourth, to find a remedy.

We are indebted to the two gentleman named above, to Messrs. George Clark, W. H. Lilley, Howard Wright and Archibald Head of Jefferson; to Mr. T. W. Forman of Divide; to H. L. Guiraud of Garo, and to Erhardt and Felding of Nathrop, for furnishing animals and rendering great assistance in the work. We are also under obligations to the Cox-Jones Commission Company of Den-

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ver for assistance in caring for the animals that were shipped there, and to Dr. J. C. Exline, U. S. Inspector in charge at Denver, for making observations.

This report is based upon personal observations made on thirty-two cases and autopsies held on six. In addition to this, several cases have been seen on which no special observations were made and no records kept.

HISTORY AND DISTRIBUTION.

This disease has been known in South Park, which is a high mountain park, varying in altitude from nine to ten thousand feet, since 1889 and in all probability existed before that time. It has been reported from North Park, which is approximately eight thousand feet, on numerous occasions. The people around Divide (about nine thousand feet) have reported many cases. It does not seem to exist to any extent in the San Luis Valley, which runs in altitude from seven to eight thousand feet, but is frequently reported from the high ranges surrounding it, when the cattle pasture on the forest reserves during the summer. It seems then to exist in the mountains of Colorado from the Wyoming line on the north to the New Mexico line on the south. We have not personally seen cases at altitudes below seven thousand feet, although we have talked with men who believe they have, and it would seem that an occasional case of a similar nature might occur at any altitude.

Thinking that other mountain states must suffer to some extent, we addressed letters to either the State Veterinarian, the Station Veterinarian, or both, of the States of Utah, Wyoming, Montana, Idaho, Nevada and California. We received replies from all except Idaho, stating that such a disease had not been brought to their notice. In spite of these negative replies, we have good reason to believe that the disease exists in the high altitudes of some of these states, although it has never seemed to assume such proportions as to be called to the attention of the veterinary officials.

In a conversation with Dr. John R. Mohler, Assistant Chief of the U. S. Bureau of Animal Industry, he expressed himself as having read something in Swiss literature of a similar disease. He has so far, unfortunately, been unable to find the article. We have addressed a letter to the Veterinary College at Berne, Switzerland, with the hope of gaining information from that source and if successful will include it in a later report.

ECONOMIC IMPORTANCE.

It is very difficult to estimate the cost of this disease to the State. During the winter of 1913-1914 one South Park stockman

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estimates that out of between four and five hundred cattle, he lost thirty calves and ten or twelve older animals. Another man lost twelve during the winter of 1912-1913. Still another says, after several years' experience, he has lost practically all bulls that he shipped in from a low altitude and he figures his loss at about five per cent. It seems conservative to estimate the annual loss at one or two per cent of all cattle above eight thousand feet. While this may seem small, yet in the aggregate it means many thousands of dollars.

TRANSMISSION.

We have tried only twice to transmit the disease, as the nature of the malady and the further investigation did not seem to warrant more work along this line. One cubic centimeter of blood was drawn from the jugular vein of case one, a seven-year-old cow, and injected into the jugular vein of a two-year-old steer. The steer was under observation for more than a year following and showed no symptoms of the disease. Ten cubic centimeters of serum were taken from the pleural cavity of case two (a calf that was slaughtered for the purpose of making the autopsy) and injected subcutaneously into the brisket of a healthy calf. This calf was under observation for more than a year and developed no symptoms of the disease.

Several cases have been known where an affected animal ran with numbers of healthy ones for weeks with no spread of the disease. No attempt has ever been made to isolate diseased animals and yet it does not appear that this practice has had any effect in spreading the disease. Later in this article we will have something to say as to the cause and it will then appear why we do not regard the disease as transmissible or even as infectious.

ANIMALS AFFECTED.

The disease has been investigated in cattle only, and seems to be much more prevalent in these animals. Man and the horse probably suffer similarly under the same conditions in occasional cases. Animals of all ages are affected, although it is not commonly recognized in young calves since these animals often die without showing the swelling of the brisket. Case number nine showed the typical lesions on post mortem examination, although at the time it was only six weeks old. Many calves die from this disease when the owners believe it to be diphtheria or some other malady.

EFFECT OF CLIMATE.

At the lower altitudes, eight thousand to nine thousand feet, the disease is more prevalent in the winter. in fact seldom appears

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in the summer, while at the higher levels up to thirteen thousand, it is a summer disease, largely, however, because cattle do not remain at these elevations in the winter. A wet cold summer is associated with a marked increase in the disease, and an especially hard winter may make a difference in the number of cases. This is rather easily explained by saying that more work is put upon the heart during cold weather and this would break down an already weakened organ all the more quickly.

SYMPTOMS.

The first evidence of the disease is a dull, listless appearance, the hair stands on end and the ears droop. The animal appears gaunt owing to failure to take the usual amount of food. There may be a slight moist cough. A diarrhoea usually appears soon after the other symptoms, or it may even be the first symptom noted. The respiration is increased and the pulse is rapid and weak. Many calves die in this stage without showing any swelling of the brisket. In some instances the appetite remains good up to within a few days of death.

Later, there appears a swelling of the loose tissue under the jaw and a swelling of the loose tissues of the brisket. Either swelling may appear first, but gradually the two merge into each other as the whole under part of the neck becomes dropsical. In male animals, the sheath may swell considerably and the hind limbs become puffy. The fore limbs may stock in extreme cases. The swelling of the brisket may become enormous in size, extending out in front of the fore limbs as a rather firm doughy mass. There is no pain on pressure and the part is not increased in temperature. The abdomen may swell markedly in its lower portion due to accumulation of fluid.

The respiration becomes increased but labored only on exercise. A moist cough is very commonly noticed. A clear mucous discharge comes from the eyes and nostrils. There is no fever. The heart-beats are increased, especially on slight excitement or exercise when they may run one hundred to one hundred and twenty per minute. Under these circumstances the beat is tumultous but lacks force as evidenced by a very weak pulse. A pronounced jugular pulse is common in the later stages.

Forced exercise in this later stage will cause labored breathing, coughing, hemorrhage from the nose, and if continued, rapid death. Consequently it is difficult to drive them to a point where they can be shipped.

The animals become very weak, so that the slightest exertion or excitement causes them to fall. This has been noticed repeatedly when attempting to restrain them for close observation.

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The blood in all cases observed has shown an increase in hemoglobin and a rather decided increase in the number of red blood corpuscles, counts averaging near twelve million per cubic millimeter for adult cattle and somewhat more for calves.* Counts made at an altitude of 9,000 feet on four normal cows, running in age from four to ten years, varied from 6,880,000 to 11,320,000. Those made on six calves from three to six months old at the same altitude ran from 11,960,000 to 21,200,000.**

The urine has never in our observation shown the presence of either albumen or sugar, although we rather expected to find the former. We have developed no suitable method for determining whether there is a greater or lesser quantity excreted in a given time.

The usual course of the disease is from two weeks to three months, although a few animals have been known to apparently recover in the spring, only to be taken down again the following fall. We may say that most animals die within a month after symptoms are first noticed, the older cattle living longer than the younger.

Death seems to be due either to suffocation, or exhaustion and paralysis of the heart.

LESIONS.

The carcass is usually emaciated. The subcutaneous tissues in the region of the brisket, lower side of the neck, and under the jaw are infiltrated with a clear. serum. It does not flow freely when incised, but can be squeezed out. Sometimes the subcutaneous tissue of the limbs is similarly affected.

When the abdomen is opened, a considerable quantity of straw colored fluid escapes, sometimes as much as six or eight gallons. The peritoneum may show a few hemorrhages and occasionally one is large enough to form a considerable mass of clotted blood (case 2.) The membrane itself in all of its folds is much thickened with the fluid above mentioned which can be squeezed out.

The walls of the stomach and intestines are thickened from the same cause. The mucous membrane of the fourth stomach and of the intestines may show small hemorrhages.

The liver is always much enlarged and is tough, firm and leathery. On section it has a grayish mottled appearance, the cut veins being very large. The condition of the liver is very noticeable and seems to be constant. On microscopic examination the grayish appearance is seen to be due to new fibrous tissue that entirely surrounds the lobules and has compressed the secreting cells until many

* In nearly all cases the blood for counting was taken from the capillaries of the ear.
** Counts made in November.

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have undergone fatty degeneration and others have entirely disappeared. The central veins are engorged with blood.

The spleen appears normal both on autopsy and under the microscope. The kidneys show passive congestion and under the microscope there is considerable dilatation of the vessels with the cells of the tubules undergoing degeneration and loosening. The pancreas and bladder are normal.

In the thorax a large amount of fluid is to be found as in the abdomen. The lungs are edematous and therefore near the lower borders a few reddened solidified and slightly depressed areas. When the animal has died of the disease the lungs may be reddened and the bronchial tubes show hemorrhages. The heart is enlarged, dilated and usually flabby. It is pale in color and may or may not be thicker than normal in its walls. It has been our experience in the limited number of cases that the hearts of the young animals are dilated and flabby with thin walls, while in the older ones there is hypertrophy with dilatation. No vegetations have been found on the valves nor any lesion that would lead to the belief that a valvular disturbance existed.

Under the microscope in three cases there has been noted excess fibrous tissue with more or less round cell infiltration. Some degeneration exists, the degenerated fibres being replaced by new fibrous tissue. Numerous *sarcosporidia* are found in every section, but no special importance is attributed to these, as they are rather common in normal animals.

The pericardium and epicardium are edematous and thickened.

DIFFERENTIAL DIAGNOSIS.

It simulates traumatic pericarditis, but can be differentiated by the fever which usually accompanies the latter disease. On post mortem examination the finding of pus in the pericardium would eliminate "brisket disease" and point to traumatism.

It could easily be mistaken for pneumonia, especially if complicated with pleurisy, in which case the brisket might be swollen. The diagnosis here would be based on the presence of fever in the live animal and on autopsy, signs of inflammation in the lungs and pleura.

We see no reason for confusing the disease with diphtheria, but since it has been done, will say that diphtheria can only be diagnosed when there are ulcers and an extremely foul odor in the mouth.

TREATMENT.

From our experience in six cases and from the experience of several stockmen, shipping to a lower altitude seems to be sufficient

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to effect a cure and where feasible is always to be recommended. The difficulty arises, first, in getting the animals to the railroad, and then in the expense of shipping after they are taken there. However, since the animals may be considered worthless, all that is received for them over and above expenses should be looked upon as clear profit. Animals can usually be hauled to the railroad and it is perfectly feasible to pay for a car for two or more of them. In some localities the affected animals can be slowly driven to a lower altitude, thus effecting a recovery. This is frequently done in the San Luis Valley, where the belief prevails that practically all recover when driven from the mountains to the valley, where the elevation is between seven and eight thousand feet. Just how much lower it is necessary for them to go cannot be said at this time, but certainly a change from nine thousand to five thousand two hundred and eighty feet has proven effective. Men in South Park believe some calves have been saved by driving them from eleven thousand to nine thousand feet elevation. In the San Luis Valley a difference of two or three thousand feet has proven sufficient. With our present knowledge, shipping or driving to a lower altitude should be first considered. If this is not possible, then medicinal treatment can be tried.

Much digitalis has been used in the form of a drench, with some quite favorable reports. It was given in the form of the fluid extract in doses of one-half to one teaspoonful once to three times daily. It appears to have been of more value in older animals, as little if any relief was noticed in calves. On the whole, it is doubtful if digitalis in this form is dependable. The fluid extract was used because of its easy administration in the hands of stockmen, although we were cognizant of the reports that have been made concerning its being rendered inert in the stomachs of ruminants. Two cases, Nos. 30 and 31, were given digitalin without favorable results. This drug is quite irritating when used hypodermically.

Certainly the animals should be kept as quiet as possible and under the minimum amount of exertion and excitement. The question arises as to whether they can be successfully treated at the altitude where they contract the disease and this we cannot answer at this time. At least it is hoped that the disease can be held in abeyance until a convenient time for taking them to a lower altitude. Strychnine given hypodermically has given no good results.

Lancing the swollen brisket and placing various medicaments within can do no good and is to be considered barbarous. It is in line with slitting the tail and putting in salt and pepper, and like the latter practice it should be eliminated as soon as possible. The

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swollen brisket is merely a symptom of a general dropsy, and a weakened heart and surgical manipulation of it can be of no value. We must either strengthen the heart or lessen its work.

PREVENTION.

Since the disease is far more prevalent in cattle shipped in from low altitudes than in natives, it would seem only wise that importations be somewhat curtailed or, if practiced, that the animals be brought more gradually to the extreme altitudes. For instance, hold them for a few months or seasons, at a moderate elevation, say seven or eight thousand feet. This practice is not likely to prevent all cases as is evidenced by reading the history of case eight, but would probably be worth while.

Since extreme exertion on first arrival at the higher level seems to play a part, more care should be taken in the handling of the animals during the first weeks to see that they are not subjected to long hard drives. Realizing that these animals are usually wild, we are aware of the difficulty in complying with this suggestion.

The practice of buying pure bred bulls from low altitudes, while praiseworthy in its intent, seems to be responsible for some of the difficulty. Not only do the bulls themselves in many instances die of the disease after some months' residence under the new conditions, but their calves appear to be much more susceptible than calves sired by native bulls. In order to reduce this source of trouble it is recommended that bulls be purchased from altitudes more nearly approaching that at which they are to be used. We believe that this practice, if followed, would do much toward eliminating the disease. Finally, it may become necessary to abandon some of the higher ranges, especially during cold and wet summers. Since the disease has not been seen in sheep it may be possible to range these animals at the higher levels where the cattle do not thrive.

CAUSE.

Whatever may be the real cause of the malady, it would seem from our work thus far, that the matter of barometric pressure as influenced by the altitude is the deciding factor in the disease. About November 10, 1913, two two-year-old steers (cases 5 and 6). affected with the disease, as evidenced by a profuse diarrhoea and marked swelling of the brisket, were shipped from Jefferson, the altitude of which is nine thousand five hundred feet, to Denver (altitude five thousand two hundred and eighty feet). They were kept in the stockyards at the latter place for a little over two weeks when the diarrhoea was checked and the swelling of the brisket had entirely disappeared. On November 28th, they arrived at the

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Station at Fort Collins (altitude five thousand feet), having been driven the same afternoon about six miles. Outside of a rapidity of respiration which might have been due to the drive, they appeared perfectly normal. They were under observation until December 17th, when, having been apparently normal since their first arrival, they were sold to a local feeder. The feeder reported that these steers fattened as well as any others in the lot and that they were sold for slaughter about April 10, 1914. No medicinal treatment of any kind was given them.

Case number seven, a yearling calf was shipped by express from Jefferson on February 11, 1914. It arrived in Fort Collins on the 12th, where, on examination, it appeared dull and had little appetite. The calf was thin, the coat staring, but the feces were of normal consistency. It was reported that the calf had had a marked diarrhoea on leaving Jefferson. After the second day the calf appeared entirely normal and remained so until March 9th, when it was returned to Jefferson, where it has since remained. On October 25, 1914, it was reported that the calf was in perfect health and had shown no return of the trouble.

On August 5, 1914, case twenty, a bull seven years old, was shipped from Jefferson to Denver (Cut No. I.). This bull had

Cut No. I. Case XX. Taken at Jefferson, Colorado, August 4, 1914, the day before shipping.

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been on a range between 11,000 and 12,000 feet above sea level. He was driven to an altitude of about ten thousand feet two weeks previous and on the day before shipping was hauled eight miles in a wagon. He arrived in Denver on August 6th, where he was unloaded in the yards and allowed to remain there under observation until August 31st. Improvement was noticed, beginning about two days after arrival, until when seen on the 19th, all swelling had disappeared, and except for being thin, he appeared normal and remained so until the 31st, since which time he has not been seen. The photograph for Cut No. II. was taken on August 19th.

Cut No. II. Case XX. Taken at Denver, Colorado, August 19, 1914, just thirteen days after arrival. Animal normal except for being thin.

Case twenty-one (Cut No. III.), a steer three years old, was shipped with case number twenty, and was given the same treatment. On the 19th he appeared much improved (Cut No. IV.), and on the 23rd he had entirely recovered.

On September 14, 1914, case number twenty-three, a yearling steer, was shipped by express from Jefferson to Fort Collins. On arrival the animal was weak, the respiration and pulse were rapid, the tail and hind limbs were soiled with dried feces, showing a previous diarrhoea; the feces at the time were of normal consistency. The steer continued to improve in general appearance until this writing, October 14th, when he seems to be normal. It has been a rather common practice among the stockmen of the San Luis Valley, when their animals became affected on the high ranges, to drive

them down to their ranches, altitude about seven thousand five hundred feet, where they usually recovered.

Altogether then there have been six cases shipped from a high altitude (9,500 to 11,000 feet) to a lower one (5,000 to 5,280) and

Cut No. III. Case XXI. Taken at Denver, Colorado, August 6, 1914, on the day of arrival, from Jefferson.

in each case prompt recovery followed. In no case was any medicinal treatment given.

One might suspect that a change of diet has something to do with it, but animals become affected both in the summer when at

Cut. No. IV. Case XXI. Taken on August 19th, thirteen days after arrival at Denver. Brisket still slightly swollen. All swelling had disappeared by the 23d.

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pasture on the mountain grasses and in the winter when the food is entirely of hay cut in the parks. Furthermore, the hay in North Park is quite different from that of South Park. Hay from both places is shipped out in large quantities to lower altitudes but there is no evidence that it has caused any such disease.

Most investigators of the effects of high altitude, agree that unacclimated people passing from a low to a high altitude notice that the respiration and heart-beat markedly increase, that there is extreme weakness on slight exertion and even fainting and hemorrhage.* Is it not conceivable that at this time extra exertion or excitement would seriously dilate the heart, which dilatation might become so extreme as to cause degeneration of the muscle walls with chronic insufficiency, resulting finally in generalized dropsy? Several cases of dilatation of the heart in man have been attributed to ordinary exertion in high altitudes before becoming accustomed to the changed conditions.

Babcock in his book entitled "Disease of the Heart" details a case where a gentleman of fifty-seven, who was accustomed to a low altitude brought on an acute dilatation by carrying a traveling bag for several blocks in Denver (altitude 5,280). He died some two years later, with typical symptoms of chronic cardiac dilatation the inference being that the injury to the heart had taken place at the time of the extra exertion in Denver.

The same author attributes another case to an exhausting journey through a snow storm at an altitude of eighteen thousand feet.

Let us consider the experience of a trainload of wild Texas steers brought from sea level to an altitude of, say ninety-five hundred feet, unloaded amid considerable excitement and driven to a distant ranch. Already the altitude with its rarefied atmosphere has made it necessary for the heart to beat much faster. Add to this the excitement and exertion incident to the animals being wild, and it is not surprising that some of them would permanently injure the heart muscle so that in some weeks or months it would fail to perform its work. Presuming that a little later the animals were driven up rocky trails and through thick forests to an altitude of from eleven thousand to thirteen thousand feet, and with this excessive exertion the wonder is that so few of them are permanently injured.

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* The Anglo-American expedition to the top of Pike's Peak as given by the editor of the Journal of the American Medical Association reported as follows: "The more immediate effects after arrival were blueness of the face and lips, nausea, intestinal disturbance, headache, fainting in some persons, and periodic breathing, besides great hyperpnea on exertion or holding the breath a few seconds."

The horses that follow these cattle are practically all raised in districts where they do their work. When asked if low altitude horses were ridden, one man answered, "They are of no use." This expresses it well. Most stockmen know that a low altitude horse is of little value for work in high altitudes until he has become acclimated. We ourselves saw a very valuable Percheron stallion that had been shipped from a low altitude to an altitude of nine thousand five hundred feet. In less than a year he suffered from heart insufficiency to such an extent that the excitement of a man passing into the corral would cause him to fall. Just previous to falling no pulse could be detected at the jaw.

A physician who practiced at Fairplay, Colorado, altitude ten thousand feet, says that most old people at that altitude die with generalized dropsy. The same man reports two cases of generalized dropsy associated with other conditions as being much improved on going to Denver. It is rather a common practice for physicians to send heart patients to a lower altitude. In a spirit of fairness, however, we should add an extract from a letter written by a physician of several years' experience in practice at Leadville, Colorado, altitude ten thousand feet. "We have acute cardiac dilatation which will cause edema, but I believe with proper treatment they will recover as well at this altitude as lower down. It is my experience as well as the experience of other physicians here that the injurious effects of high altitudes have been much exaggerated, especially so in those born at this elevation."

In support of this contention, that the altitude is the important factor, we submit the following additional facts. There are four stockmen in South Park who seem to have more trouble than any others. These men range their cattle in the summer above timber line at an altitude above eleven thousand feet, which is one of the highest ranges in the United States.

The range near Buena Vista that runs from eleven thousand to thirteen thousand feet had not been used by cattle previous to the summer of 1914 when, as detailed under case twenty-four, twelve animals were lost out of one hundred and sixteen. The owners had ranged cattle at altitudes approximating eight thousand feet for several years, with no bad results. Cattle shipped from a low altitude are always more affected than those native to the country. There are several instances where a number of low altitude cattle have been shipped to South Park with markedly disastrous results. One man says that in several years' experience he has never yet shipped in a bull from a low altitude that did not sooner or later die of this disease. Is it not probable that some of the calves from these bulls would show a similar weakness in this

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respect, thus explaining the high mortality in calves? That is, as we look upon the problem, it requires a stronger heart to carry an animal through the vicissitudes incident to an existence at a high altitude than it does at a low one. Some hearts, in fact most of them, have sufficient reserve force to meet the new conditions, as is evidenced by the rather common observation that hearts of cattle at high altitudes are heavier and thicker (hypertrophy) than those lower down. Some animals, however, do not have this reserve force and exhaustion of the heart with dilatation results. Such animals would undoubtedly give rise to a certain number of offspring whose hearts would be insufficient to meet the vigorous conditions.

CASE REPORTS.

CASE No. 1.—Black and white cow, age seven or eight; weight nine hundred and fifty. **History**—Noticed to be ailing the previous summer; swelling appeared under jaw about three weeks before; later, swelling of the brisket. About the 27th of March she refused food for a couple of days. On March 30 the swollen brisket was lanced, after which she seemed to improve, and drank more water than usual. Seen on April 5, 1913, near Jefferson, Colorado; altitude nine thousand feet; in fair flesh; rather wild, so that restraint was resisted and only accomplished after much excitement on the part of the animal. Following this, the temperature was 103° F.; respiration rapid with whistling sounds in trachea. An attempt was made to tap the swelling under the jaw without results. There was no weakness, feces very thin, and watery discharge from the nostrils, owner thinks animal better. One cubic centimeter of blood was removed from the jugular vein and injected into the jugular vein of a healthy steer. Cow remained in poor condition throughout the summer and was shipped out in the fall, passing from observation.

CASE No. 2.—Hereford steer, short, yearling, South Park, altitude nine thousand feet, raised there. **History**—Noticed to be sick about a week previous; seen on April 6, 1913, in fair state of flesh; respiration not labored but slightly increased, moist cough; temperature 102.6; appetite good; feces quite thin and dark in color; no mucous or blood; brisket swollen and flabby; April 7th, temperature 101.9. Calf eating, appears strong. Brisket swollen more than on day previous and rather more firm on pressure. Diarrhoea marked, feces dark in color. Abdomen enlarged. April 8th, increase in swelling of brisket with thickening of lower part of neck. Diarrhoea continues. Temperature 102.5. Jugular pulse well marked. April 9th, symptoms same as on previous days. Temperature 101.8. Slaughtered for examination. Post mortem examination.—Large edematous area at the brisket estimated to be ten inches long by eight inches wide. About three gallons of straw-colored fluid in the thoracic cavity. Considerable in the pericardium. Large blood clot the size of one's fist in the right lung near the dorsal part and just above the point where the bronchus enters. Collapsed red areas in the apical and cardiac lobes near the lower margin. By far the larger part of the lungs appear normal.

Estimated three gallons of fluid in the abdominal cavity. Mesentery very much thickened throughout its whole extent. Fluid can be easily squeezed out. Large blood clot near anterior mesenteric artery. Several small hemorrhages under the serous membrane. Liver enlarged and hard, on section is mottled gray. Spleen normal. Interior of rumen and reticulum black. Folds in the fourth stomach very edematous.

Many ulcers in the mucous membrane most of which are healed. Several reddened areas, some sand present. Mucous lining of intestine loosened and easily torn off. Intestinal contents thin, watery, no bad odor. Kidneys petechial. Bladder normal.

CASE No. 3.—Grade Hereford, black with white face, age one year, weight three hundred pounds. Found sick four days before. Altitude nine thousand five hundred feet. Seen on September 29, 1913. Grunting with every breath, dull, listless, mucous discharge from eyes; mucous membrane pale; jugular pulse very marked; jugular veins so full that they stand out and are plainly visible some yards away; no appetite; drinks freely; thin fetid diarrhoea; temperature 101.6; respiration 30 and audible; pulse 90; heart tumultous; brisket enormously enlarged and rather firm on pressure; some regurgitation of gas; coughs frequently; animal died during the night of September 30. **Post Mortem**—Subcutaneous tissue markedly edematous over brisket and under surface of the neck, extending as far back as umbilicus and forward to the symphysis of the lower jaw; enormous quantities of fluid in the thoracic cavity; heart enlarged and dilated; lungs congested in spots; bronchitis, due to a considerable number of lung worms; hemorrhagic spots in tissues about the pharynx and trachea; hemorrhages under the peritoneum at several places, an especially large one under the spleen; spleen normal; liver hard, enlarged and mottled on section; kidney passively congested; mucous membrane of the fourth stomach and intestines reddened throughout; a large quantity of fluid in the abdominal cavity; the serous membrane of the intestinal walls is much thickened by edema.

CASE 4.—Yearling calf, weight three hundred and fifty pounds; seen on September 29, 1913; altitude nine thousand feet. The previous day he had been driven in off the range, but owing to his failure to travel well has been left behind. **Symptoms**—Profuse diarrhoea, not dark in color; very weak and grunting; brisket greatly swollen as well as the loose tissues under the jaw; mucous and watery discharge from the eyes; dull; listless; temperature 101.1; respiration 18; pulse 100. Slaughtered on the morning of the 30th for examination; a few hemorrhagic areas on the rumen; estimated a couple of gallons of fluid in the abdominal cavity and as much in the thoracic; mesentery edematous; four rather large ulcers in the fourth stomach; no reddening in either the stomach or intestines; liver enlarged and quite hard, being mottled on section; lungs normal except a few small areas in dependent portions of the cephalic and cardiac lobes, which are solidified and depressed; heart not large but quite flabby; no lung worms and no bronchitis.

CASES No. 5 AND 6.—Two two-year-old steers with badly swollen briskets and showing profuse diarrhoea, shipped from Jefferson, Colorado, altitude nine thousand feet, to Denver, where they remained in the stockyards for three weeks, during which time they completely recovered. They arrived at the Station at Fort Collins on November 28, 1913, in a normal condition, were kept under observation until December 17th, when they were sold as feeders. The purchaser reported that they fed out as well as any others in the lot and were sold for slaughter about April 10, 1914. One of these steers came originally from either New Mexico or Arizona and the other from Marysville, Utah.

CASE 7—A calf raised at Jefferson, Colorado, altitude nine thousand feet, shipped to Fort Collins by express on February 11, 1914, because of a marked diarrhoea. dullness. swelling of the abdomen and droopy ears, denoting brisket disease. On arrival the following day the feces were normal, the animal was weak and dull with little appetite. No swelling of the brisket; temperature 102. It became brighter in a few

days and continued to improve until within a week it was normal. The calf was returned to Jefferson on March 9, 1914, since which time there has been no recurrence of the disease.

CASE 8.—July 1, 1914. Three-year-old steer, grade Shorthorn, altitude nine thousand two hundred feet, Divide, Colorado. **History**—One of a bunch of yearlings brought from Nebraska to an alaiaude of about eight thousand feet, near Manitou. Present owner bought them the spring previous and had lost one other steer similarly affected; been sick for four weeks. **Symptoms**—Brisket moderately swollen, no appetite, dull, thin, staring coat, swollen under the jaw; scouring badly but feces not black; respiration hurried. He was given a teaspoonful of fluid extract of digitalis by the mouth on July 2 and 3. On the 4th he was given two doses of a teaspoonful each, one in the morning and one in the evening. On the 5th three doses were given. He grew steadily worse until some time during the night of the 5th, when he died. **Post Mortem Examination**—Subcutaneous tissue markedly edematous throughout the region of the brisket, neck, intermaxillary space and over all four limbs;

Cut No. V. Case VIII. Taken on July 2, 1914, at Divide, Colorado, three days before death.

lungs collapsed in a few small areas, the left one showing a few hemorrhages; tracheal and bronchial mucous membranes hemorrhagic; no parasites; a large quantity of fluid in the thorax; heart enlarged with thick walls; epicardium edematous; several gallons in the abdomen with all of the serous membrane and walls of the hollow viscera decidedly thickened with fluid; mucous membrane of fourth stomach and intestines reddened over entire area. Liver very dark, hard and enlarged, mottled on section; spleen normal and kidneys showing congestion. An abscess estimated as holding a pint of pus was found in the wall between the reticulum and the omasum; there was a blackened wire nail in it; it did not, however, extend through the diaphragm into the thorax.

Case 9.—Female, calf, aged six weeks, Shorthorn. **History**—Been on the range at an altitude between eleven thousand and twelve thousand feet along with cases ten to twenty-one, inclusive. This case is given especially because it represents a typical one picked out from a number of others that were supposed to have diphtheria. It was also stated that one man had lost thirty calves during the previous year similarly affected and that this year many were dying from the same affection. An examination of the mouth of a considerable number revealed no ulcers nor any diseased condition, consequently this one was picked out for autopsy. It had been sick for two weeks, brought to ranch nine thousand feet, a week before. **Symptoms**—In good flesh, but the flanks are sunken, due to failure to suck; hair is standing on end and ears droop; seems to have considerable strength; no noticeable swelling of the brisket or submaxillary space; coughs occasionally; some diarrhoea. **Autopsy**—Edema of the loose tissues surrounding pharynx and larynx; estimated that there was a gallon of fluid in the thorax, as much in the abdomen and a pint in the percardium; lungs normal except for a few collapsed and red areas near ventral border; heart flabby and dilated; peritoneum and walls of the hollow abdominal organs markedly edematous; liver enlarged and hard, being mottled with gray on section. The interior of the intestines and stomach are pale, being due probably to the fact that the animal was bled before examination.

CASE 19.—August 3, 1914. A calf that was presumed to be sick like the others, but had been in pasture at about nine thousand five hundred feet. It had developed a swelling of the brisket during the night previous to our visit and was very dull and grunting when seen; diarrhoea marked; died on the night of August 4.

CASE 20.—Shorthorn bull, pure bred, age 4 years; raised at Golden, Colorado, altitude about five thousand five hundred feet; was purchased and shipped to South Park (nine thousand feet) in June, 1913. During the following winter he developed a considerable swelling of the brisket. Digitalis was given at the rate of one-half teaspoonful of the fluid extract daily. He recovered in about a month and in the spring was sent with the other cattle to the range between eleven thousand and twelve thousand feet. He was noticed to be ailing about the middle of July and a week later his brisket was swollen and he was driven down to an altitude of about ten thousand feet; seen on August 1. **Symptoms**—Stands in shade, seldom moves, dull, no appetite; brisket swollen enormously; sheath swollen; legs thickened and edematous, the hocks being especially puffy; ears drooped; no diarrhoea. On August 4th he was hauled eight miles in a wagon to Jefferson, where he was loaded with Case 21 and shipped to Denver. On the 6th of August he was apparently gasping for breath, his mouth was open and he was very dull. (It was a very hot day and the animal was in the sun.) However, his appotite seemed good. On August 10th the swelling of the brisket had decreased fully one-half; appetite good; on the 19th all trace of swelling had disappeared and he was normal except that he was thin. He was sold on the 31st as a feeder and passed out of our observation.

CASE 21.—Grade Shorthorn steer, three years old. **History**—Raised in Texas and purchased in Denver a year previous; found ailing the latter part of July on the range at altitude above eleven thousand feet; driven to ranch (nine thousand feet) where he had for two weeks received digitalis daily without avail. Shipped to Denver on August 5, 1914, where he showed the following symptoms on arrival. **Symptoms**—Dull, little appetite, ears drooped; respiration labored, panting; brisket swollen enormously, rather firm and hard on pressure; feces normal. On August 10th he was eating well and appeared brighter, but the swelling

was about the same as on the 6th. On the 19th much brighter, swelling of brisket nearly all gone, that which was left being flabby. On the 23d he appeared entirely normal and was sold as a feeder on the 31st.

During the time cases twenty and twenty-one were in the stockyards at Denver, they were under close observation by the inspectors of the U. S. Bureau of Animal Industry.

The following data is appended as kindly submitted by Dr. J. C. Exline, Inspector in Charge.

Denver, Colorado, September 25, 1914.

Dr. J. C. Exline,
Inspector in Charge,
Denver, Colorado.

Sir: August 5, 1914, there was received at the Denver Union Stockyards from Jefferson, Colo., one red bull, weight about 1,200 pounds, and one red and white steer, weight about 1,000 pounds, held for observation, account so-called "Brisket Disease." Animals found to be emaciated, an edematous condition noted, extending posteriorly from sub-sternal to scrotal region; between forelegs it was from 12 to 15 inches wide, pit on pressure, apparently filled with an exudate which involved the inferior thoracic-abdominal region, and legs. The following temperatures have been recorded:

Aug. 6.	Bull— 3:00 p.m.	101.8	Aug. 6.	Steer— 3:00 p.m.	101.4
Aug. 7.	Bull— 9:00 a.m.	101.4	Aug. 7.	Steer— 9:00 a.m.	101.2
Aug. 8.	Bull— 8:30 a.m.	100.3	Aug. 8.	Steer— 8:30 a.m.	101.2
Aug. 8.	Bull— 3.00 p.m.	101.2	Aug. 8.	Steer— 3:00 p.m.	102.4
Aug. 9.	Bull—11:00 a.m.	101.2	Aug. 9.	Steer—11:00 a.m.	102
Aug. 10.	Bull— 8:30 a.m.	100.8	Aug. 10.	Steer— 8:30 a.m.	101
Aug. 10.	Bull— 3:00 p.m.	104.4	Aug. 10.	Steer— 3:00 p.m.	103.2
Aug. 11.	Bull—11:00 a.m.	101.6	Aug. 11.	Steer—11:00 a.m.	103
Aug. 11.	Bull— 4:00 p.m.	104	Aug. 11.	Steer— 4:00 p.m.	104
Aug. 12.	Bull— 9:00 a.m.	101.8	Aug. 12.	Steer— 9:00 a.m.	102.6
Aug. 13.	Bull— 9:00 a.m.	101.8	Aug. 13.	Steer— 9:00 a.m.	102.2
Aug. 14.	Bull— 9.00 a.m.	101.2	Aug. 14.	Steer— 9:00 a.m.	100.6
Aug. 27.	Bull—10:00 a.m.	101.8	Aug. 27.	Steer—10:00 a.m.	102
Aug. 28.	Bull— 9:00 a.m.	101	Aug. 28.	Steer— 9:00 a.m.	101.2
Aug. 28.	Bull— 3:00 p.m.	102.6	Aug. 28.	Steer— 3:00 p.m.	101.8
Aug. 29.	Bull— 9:00 a.m.	101.6	Aug. 29.	Steer— 9:00 a.m.	101.2
Aug. 29.	Bull— 3:00 p.m.	102	Aug. 29.	Steer— 3:00 p.m.	101.8

Pulse found soft and weak first few days. Urination frequent, normal in color—the high temperatures probably due to being in open pens several days. Animals apparently regained normal condition and were shipped as feeders to Omaha, Neb., August 31, 1914.

Very respectfully,
A. W. SWEDBERG,
V. I., Yards.

Denver, Colo., October 6, 1914.

Dr. J. C. Exline,
Inspector in Charge.

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Sir: The following observations were made and temperatures taken for a period of eleven days, on two cases of brisket disease—bull and

steer—at the Denver Union Stockyards:

Subject: Shorthorn bull, about five years old, in poor condition, with considerable swelling of brisket.

TEMPERATURE.

10 a.m.		3 p.m.
Aug. 15.	101.6	
Aug. 16.	No temperature taken.	
Aug. 17.	100.8	102
Aug. 18.	101	101.6
Aug. 19.	101.4	102
Aug. 20.	100.6	100.8
Aug. 21.	100.6	101.8
Aug. 22.	101.4	100.2
Aug. 23.	100.4	
Aug. 24.	101.4	101
Aug. 25.	101	103.8

The swelling of brisket generally lessened from day to day until on the day of the last observation it had almost entirely disappeared.

Subject: Steer, grade, about four years old, in poor condition, brisket very much swollen.

TEMPERATURE.

10 a.m.		3 p.m.
Aug. 15.	102	
Aug. 16.	No temperature taken.	
Aug. 17.	102.6	102.4
Aug. 18.	101.6	102.4

Diarrhoea was present up to this date when the evacuations became normal.

TEMPERATURE.

10 a.m.		3 p. m.
Aug. 19.	101.8	101.8
Aug. 20.	101.4	102
Aug. 21.	100.8	101.4
Aug. 22.	101	101.4
Aug. 23.	100.6	
Aug. 24.	100.6	101.2
Aug. 25.	100	103

There was still considerable swelling of brisket on this date, but it had lessened from day to day during the period of observation.

The high temperature of both bull and steer, at 3 p. m., on August 25, were probably due to the animals being removed from a covered shed to an open corral.

During the period of observation, both animals ate well and drank freely.

Very respectfully,

H. B. CHANEY, V. I.

CASE 23.—Yearling steer, grade Hereford; raised at an altitude of about nine thousand feet; was noticed to be ailing some two weeks before shipping out. Two days after shipping the brisket was markedly swollen and diarrhoea was profuse. On the day of shipping, however, the brisket was not swollen. Arrived at Fort Collins September 15, 1914. He was extremely weak and rather dull, appetite good, hind limbs covered with feces showing a previous diarrhoea; respiration 120; heart-

beat could not be obtained under normal circumstances; no swelling of the brisket. Animal became brighter and added flesh until this writing, when he is perfectly normal.

CASE 24.—Two-year-old Hereford steer, one of a bunch of one hunhundred and sixteen steers shipped from Panhandle, Texas, in March, 1914, to Nathrop, Colorado, altitude seven thousand six hundred and ninety-six. On May 1st they were driven to a range between ten thousand and thirteen thousand feet, where they remained until September 27th. During this time seven had died with what appeared to be brisket disease and on September 27th six were sick and four were missing. Case 24 had been driven the previous day to an altitude of a little less than eight thousand feet, where, owing to exhaustion he and one other had been left, the other sick ones being taken to an altitude of a little less than eight thousand feet. On September 28th, the brisket and loose tissue of the jaw were badly swollen; there was profuse diarrhoea; the animal was very weak and grunting; respiration 36; pulse 120 and very weak; heart bating tumultously; moist cough; did the following day while being transported in a wagon to a lower altitude. Two others of this group died within the next two weeks in spjite of the fact that they were removed to an altitude of eight thousand feet.

CASE 28.—Seen August 16, 1913, ten miles above Morrison, on Bear Creek, altitude seven thousand feet. **History**—Jersey cow, seven years old; taken from Littleton, January 10, 1913, driven to Canfield's ranch, stood the journey well. Canfield thinks the brisket might have been slightly swollen at that time. A month later the cow was constipated, had desire for salt and drank much water. A nasal discharge was noticeable. The brisket enlargement partially disappeared for a time; heart beating violently. July 15th diarrhoea was present and feces had offensive odor; weakness, anorexia, malaise, indisposed to move. **Symptoms**—Temperature 102.5; respirations labored; fore feet wide apart; offensive diarrhoea; temperature of body evenly distributed; heart beating fast and labored; pulse full and hard; jugular on right side was corded, the size of a man's wrist, extending from the bifurcation near angle of jaw downward for ten inches; an old scar was found in the region of the throat and over the jugular, looked as though it might have been surgical. **Post Mortem**—Cow was destroyed by bullet in head and bleeding; test with hemoglobin scale indicated one hundred per cent; edema of brisket extreme and not extended to the lower pectoral region; edema not present in extremities; great quantities of sera found in thorax and abdomen; edema of mesentery and areolar tissue in region of brisket; heart muscles flabby and showing some degeneration; right side of heart dilated and no excessive accumulation of fluid around the heart; lungs normal save a wash-out appearance; spleen normal; liver much enlarged, hard and nutmeg appearance; blood seemed to coagulate normally; bowel contents fluid and nearly empty; a thrombus fully six inches long in jugular vein; kidneys appeared slightly congested but otherwise normal. The cow was in good flesh when symptoms first appeared and did not show debility, fever and disturbances of reflexes, volition, etc., that would be expected in case of infection.

CASE 30.—Yearling, Hereford heifer; weight 500 pounds; altitude nine thousand feet; near Hartsel, Colorado. **History**—One of a bunch of southern heifers shipped into South Park on May 13, 1914, and pastured at an altitude of about nine thousand feet during the summer. She was noticed to be sick about the middle of October when the roundup took place. Seen on November 6, 1914, at which time there was a moderate swelling of the brisket, a puffiness under the jaw and a very much distended abdomen. She was thin, weak, had little appetite and a rather profuse diarrhoea.

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November 7.—Pulse 120 and weak; temperature 103.2. The thorax was tapped with trocar and cannula, but not to exceed a pint of fluid was obtained. Four gallons of fluid were drawn from the abdomen, which noticeably reduced its size. At 8 a. m. ¼ gr. digitalin was given hypodermically; at 1.30 p. m. ¼ gr. digitalin and ¼ gr. strychnine; 5 p. m. ¼ gr. digitalin.

November 8.—Brisket swollen more than on previous day, abdomen slightly fuller than after tapping. One-fourth gr. digitalin and ¼ gr. strychnine given morning and evening.

November 9.—Brisket and abdomen same as on previous day. Same medicament as on previous day. Red blood corpuscles 14,120,000.

November 10.—Weak; temperature 102.3. One-fourth grain digitalin and ¼ gr. strychnine morning and evening.

November 11.—One-eighth grain digitalin and ¼ gr. strychnine given in the morning. Animal very weak. Died within thirty minutes after the last dose of medicine.

Post Mortem.—Carcass emaciated. Subcutaneous tissue edematous on under surface of jaw, neck, chest and part of abdomen; probably a gallon of fluid in the thoracic cavity and a small amount in the pericardium; lungs normal except lower portion of cephalic and cardiac lobes which appear reddened and collapsed; heart much dilated and flabby even the left ventricle collapsing as does the right in some cases; no macroscopic valvular lesions. Abdominal cavity contained a small amount of fluid, the mesentery and subserous tissues throughout being markedly edematous. Liver enlarged and hard. mottled on section. Spleen normal, other organs normal except for generalized edema. Areas of necrosis on the side of the neck evidently resulting from the digitalin.

CASE No. 31.—Hereford heifer, yearling, shipped to South Park from the South previous spring in same bunch as No. 30. Noticed to be sick on week previous to date of our first visit by exhibition of diarrhoea followed later by a distended abdomen. Seen on November 6, 1914. Animal in fair state of flesh, rather strong, appetite good, diarrhoea, slight swelling under jaw, none of the brisket, abdomen distended moderately. Was treated approximately as No. 30 until November 11, when she, being very weak and the swelling of the brisket being quite marked, treatment was discontinued. The swelling of the neck due to the digitalin was very noticeable. Her pulse ran between 100 and 120 during the time of observation with a temperature varying from 102 to 105.5, the high temperatures being charged to the abscesses produced by the digitalin. The red count on November 9th was 16,200,000.

SUMMARY.

A disease occurs in cattle in the high altitudes of Colorado, the principle symptoms of which are swelling of the brisket and of the loose tissues under the jaw, usually diarrhoea and a moist cough with gradual emaciation and death.

It is chronic in character but is fatal in practically all cases.

On autopsy the most marked features are general dropsy, enlarged and hard liver and dilated heart.

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In six cases shipped to a lower altitude (about five thousand

feet) all recovered without other treatment, although it seems reasonable to believe that they would have died had they not been shipped.

It appears to be caused by an exhaustion of the heart muscle associated with a varying degree of dilatation and hypertrophy and this being brought about by exertion before acclimatization at high altitudes, or in the case of calves, inherited cardiac weakness.

Medical treatment has so far proven of little avail, but where possible shipping the affected animals to a lower altitude is recommended.

Preventive measures include the use of bulls that have been raised at altitudes of eight thousand feet or more, with a view to building up a hardier strain of cattle, also the curtailment of indiscriminate shipping of low altitude cattle to high altitudes.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

Yellow-berry in Wheat

ITS CAUSE AND PREVENTION

By WM. P. HEADDEN

PUBLISHED BY THE EXPERIMENT STATION
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The Agricultural Experiment Station

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YELLOW-BERRY IN WHEAT—ITS CAUSE AND PREVENTION

By Wm. P. Headden

In the prosecution of the study of Colorado wheats which we now have been carrying on for two years, we find that the condition designated as yellow-berry constitutes one phase of it which we think is of sufficient interest to justify us in presenting it at this time.

The question is in no way a new one, still there seems to be considerable confusion regarding it, while its cause has been assigned to very different agencies and no positive claim made to any direct means for its prevention.

The term "yellow-berry" is used to designate a condition of the wheat kernel which gives it a mottled appearance, due to internal white spots. In bad cases, the whole berry may be affected, when its color will vary from white to a light yellow according to the color of the outer layers or covering of the kernel. Such kernels are more or less opaque when viewed in transmitted light. Normal kernels are uniformly flinty or glassy in appearance and are translucent when viewed in transmitted light.

I do not know when the first mention of it was made, but it evidently existed in Hungary in 1900, for Kosutany in his work on "Der Ungarische Weizen und das Ungarishe Mehl" makes definite mention of flinty, mealy and half mealy kernels. I take it further that his expression "degree of mealiness," as applied to wheat, is probably nothing else than the extent to which the grain was affected by what we call yellow-berry. I suppose that it was well known before this, for it is spoken of in such matter of fact way, without further description or definition, that one assumes it to have been considered by the author as a familiar subject. This, however, is the first mention of it that I know of in such a way as to indicate a general condition of a crop. As just stated, there is no further comment on its characteristics. The grain is specified as flinty, mealy and half-mealy. There is no question but that these different kinds of kernels occur in the same variety and lot of wheat for the percentage of each kind of kernel is given. Schinder in Der Getreidebau, 1907, also mentions mealy and half-mealy kernels.

The next definite mention that I find of it was by H. L. Bolley. South Dakota Station Report 1904, pp. 35-36. Next by Lyon and Keyser, Nebraska Bulletin 89, 1905. These authors seem to have

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had their attention directed to the subject by the complaints of farmers, grain dealers, and millers. Their statement is that the investigation of this subject was begun in 1902. Following this in 1908, Bulletin 156 of the Kansas Experiment Station on "The Yellow-berry Problem in Kansas Hard Wheats" appeared. It would appear that others, among them Prof. H. Snyder of Minnesota Experiment Station, had discussed the same question without designating it by any special name.

The first and most important question regards its effects upon the quality of the grain. I find no definite data given upon this subject. Lyon and Keyser give a measure of the injury to the Nebraska crop in terms of loss to the farmer. This is put down at from one-half to one million dollars annually. This was the estimated loss on a market where the wheat was not sharply graded, many of the millers making no difference at all in the price. I have been informed that Kansas and Oklahoma at times have suffered to a much greater extent in the matter of market values than Nebraska, because their wheat sought a market where the grading was much stricter. I have found an instance in Colorado in which a mill would not buy yellow-berry wheat, at any price. The reason given me was that one could not be sure of the quality of the flour turned out. This particular mill was blending winter and spring wheats. The sample in question was a winter wheat, Turkey Red, and was very badly affected by yellow-berry. That the generally accepted effect of this affection on the value of the wheat is a detrimental one, is indicated by the use of the term "deteriorated wheat." We find this term used quite frequently when it is difficult to know just what is meant by it.

Lyon and Keyser established the fact that the yellow-berry kernels contained less nitrogen than the flinty or horny ones, so that there is more in the problem than a prejudice on the part of the wheat-buyers. If we are correct in using the percentage of nitrogen present in wheat as a measure of its value, these yellow-berries are really inferior to the flinty ones, and this is a good reason why they should command a lower price.

If there is any sharp and satisfactory distinction between the use of the terms yellow-berry and soft wheats, I have failed to notice it. I am strongly inclined to think that such a distinction should be made, but it does not seem to have been made and there is certainly some confusion. The California and Oregon wheats are spoken of as soft, starchy wheats. The yellow-berry wheats are spoken of in the same way, but that the same thing is meant in the two cases is not clear. It is, however, true, I think, that they are low in protein, high in starch, and light in color. Wheats af-

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fected by yellow-berry are, especially when the whole berry is involved, white, or, if the outer covering is highly colored, yellowish. They are always opaque. This is an extreme condition. The whole of the berry may not be involved, and then the portion not involved is translucent. The Defiance, a spring wheat, is normally a medium amber colored, translucent wheat, but when affected by the yellow-berry may be wholly of a dull white color and opaque. I really do not know the proper classification of our Defiance wheat. It certainly belongs to the light colored spring wheats, but it cannot be said to be low in nitrogen as it ranges from 1.8 to 2.4 per cent, for samples taken over two consecutive years. If we express this in terms of protein we have, using 6.25 as our factor, from 11.25 to 15.0 percent protein, or using 5.7 as a factor, we have from 10.26 to 13.08 percent protein, so that there seems to be a satisfactory amount of protein present and the starch cannot be excessively high. Still a normal kernel of this wheat is a very different thing from one wholly affected with the yellow-berry which is white, opaque, and has a certain roughness, the appearance of a loose structure. All such kernels when crushed between the teeth are soft and mealy.

The affection may occur in one or in both halves of the kernel as a sharply defined spot, either large or small, so that we find the kernels designated as "spotted." One-half of the kernel may be involved throughout or there may be a strip along the back of the kernel. When viewed in transmitted light, we often observe the affection as small, opaque spots, or one-half of the berry is either opaque or more or less strongly clouded. It follows that when viewed in transmitted light, we have kernels wholly translucent, translucent with dark spots, one-half translucent, or cloudy and wholly opaque.

Writers on this subject are agreed that it is a more or less serious affection. They also agree in regard to its appearance, but when they come to consider the cause of it they are not agreed at all. So far as I can find, only three of the works mentioned assign any cause. Prof. H. L. Bolley in the North Dakota Station report, 1904, part I, pp. 35-36, seems to have been the first to assign a definite cause for it. It seems, however, to have been referred to before this, but in such a general way that subsequent explanation is required to definitely relate the statements to this affection. Prof. Bolley says:

"Considerable attention has been given to the cause of starchy, spotted grains in hard winter wheats, the trouble being known locally as 'White belly.' Grains of this character are generally graded as soft wheats and are believed to be inferior to the hard wheats of the North-

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west. A number of experiments were carried on in which germination trials, microscopical tests, and cross-fertilization trials were made and also the effect studied of exposure of harvested bundles to the ordinary weather conditions."

"From the results the author believes that the white spots are not due to crossing, nor are they matters of heredity, but that this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is yet in the chaff. If the weather action is long continued the grains become evenly bleached over the entire surface. The color and hardness of the grain can be maintained by proper care in harvesting and curing."

It must be borne in mind that Prof. Bolley's conclusions are based upon the results of experiments and observations made for the purpose of discovering the cause of this affection and these conclusions exclude crossing and heredity as causes of it, but predicate the action of moisture, air and sun as its cause and care on the part of the owner as its cure or rather that it can thereby be avoided.

Lyon and Keyser arrived at a similar conclusion based upon very similar experiments. Lyon and Keyser, Nebraska Bul. 89, (1900), p. 27, say:

"To see if the Yellow-berries were due to bleaching by sun and weather after harvest, sheaves were taken from the same portion of the same plot, one-half being left exposed and the other half cured in a dry room which was only moderately lighted. The sheaves were cut July 10, 1903. The exposed bundle was left out until Aug. 21, 1903, the only protection given being a frame of wire netting having a mesh small enough to keep out sparrows. In September the bundles were carefully thrashed and the grain separated into two portions, 'Yellow Berry' and 'Horny Red,' keeping each bundle by itself. The bundle kept in a dry dark room had twenty-five per cent of yellow-berries, while the exposed bundle had ninety-seven and two-tenths per cent yellow-berries."

"Other noticeable changes took place. The grain from the protected bundle was bright and of good, clear color. The grain from the exposed bundle was very much discolored and so badly bleached as not to be marketable."

This experiment was repeated in 1904 with practically the same result. These authors also investigated the effect of the degree of maturity or the time of cutting upon the amount of yellow-berry. The result was that grain cut 7 July, 1904, contained seven and six-tenths percent, and that cut when over-ripe nineteen percent. an increase of eleven percent. The relation of the weather, character of the season, was also considered. On investigating this subject they arrived at the following conclusions:

"In the crop of 1901 there was 10.5 per cent; in the 1902 crop 4.3 per cent; in the 1903 crop 25 per cent of yellow-berries, and in the crop of 1904, 20 per cent of yellow-berries. There is quite a definite relation between the per cent of yellow-berries in the crop and the character of

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the season in so far as the latter affects the date of ripening, the composition and the yield of wheat."

The authors base a suggestion for the lessening of the percentage of yellow-berries upon these observed facts, recommending early cutting and prompt stacking. They further discuss the composition of the 'Horny Red' and the 'Yellow Berries,' showing that there is a decided difference in this respect, the horny kernels being the richer in nitrogen and also the heavier; further, that the yellow-berries had larger starch grains and more air spaces, vacuoles, and cite Nowachi[1] as suggesting **"as early as 1870 that the difference in appearance between mealy and horny wheat kernels is due to the presence in the former of a larger volume of air spaces than in the latter."** Again they say: **"It appears that large starch granules and large and numerous vacuoles are associated in yellow kernels, the white appearance of the endosperm being due doubtless to the latter."**

They also quote Hackel[2] as follows:

"If the albumenoids so fill up the intervals between the starch grains that the latter seem to be imbedded in cement, the albumen appears translucent and the fruit is called corneous; but if the union is less intimate, there remain numerous small air cavities and the albumen is opaque and the fruit is mealy. Both conditions may occur in the same variety (wheat) and they seem to be occasioned by differences in climate and soil."

In their summary, p. 50, they again formulate these conclusions admirably as follows:

" 'Yellow-berry' in hard winter wheat causes an annual loss to the wheat raisers of Nebraska of from one-half to one million of dollars. The chief cause of this condition is allowing wheat to become over-ripe and failure to stack the sheaves.

" 'Yellow-berries' as compared with hard, red ones have a lower gluten content, and are lighter in weight."

In 1908, Professors Roberts and Freeman, Kansas Bul. 156 discussed the subject under the title, "The Yellow-berry Problem in Kansas Hard Winter Wheat." This yellow-berry is considered the most serious problem confronting the wheat growers of Kansas and the characteristics of the affection are described in detail. The yellow-berry is sharply distinguished from berries bleached by exposure, which seems to me a fair distinction and one not heretofore made. The authors say:

"It should further be emphasized that the bleached, opaque grains due to weathering are not yellow-berries. In weathered kernels the grain has an opaque and rather dirty, grayish yellow aspect which ap-

1. Untersuchungen uber das Reifen des Getreides, Halle, 1870, pp. 76-77.
2. The True Grasses, E. Hackel (Trans. Scribner & Southworth), p. 26.

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pearance affects the grading of the grain adversely, but is not necessarily associated with an inferior condition of the kernel, although such frequently is the result of exposure to the weather."

While this statement stands in opposition to the conclusions of the preceding investigators, it seems to me to be worthy of consideration. If I understand Lyon and Keyser aright, they claim that there was a decided increase of yellow-berry after the grain was cut, but do not claim that all of the weathering effects are to be classed as yellow-berry. On the contrary, the statements that they make tend to convey the idea that they attribute the increase in the amount of yellow-berry after cutting to the continued absorption of carbohydrates from the plant after cutting, still their statement of the chief cause includes weathering after cutting. The view presented in the Kansas bulletin is that the yellow-berry is caused by some physiological condition and is a heritable quality as the following statements show:

"The yellow-berry, then, appears to be distinctly a physiological growth product due to certain conditions thus far not clearly analyzed or satisfactorily explained. The essential thing, from the practical standpoint is to discover whether pure stocks of wheat can be found which produce constantly a minimum amount of yellow-berry in the hard wheat region and in localities in which the yellow-berry ordinarily occurs."

These writers consider the subject an important one for Kansas and refer to it as a factor in the deterioration of their wheat.

"Any factor that brings about deterioration in the grade of this wheat (Kansas winter wheat, H.) calls for serious investigation. The yellow-berry is such a factor. The presence of the yellow-berry in any quantity in our hard wheat affects unfavorably its commercial grading and its market price."

As to the cause of it, or to what they believe to be the cause of it, they are not as definite as could be desired. I have already stated that they consider it a "physiological growth product" and that it is an heritable character, still, as is readily understood, climate and growing conditions in general, are not without influence. These authors evidently consider them of great importance for they approvingly quote Schindler, Der Weizen, Berlin, 1895, as follows:

"With the length of the vegetative period, especially with the extent of the interval between blossoming and ripening, not only the dimensions of the kernel increase but also the quantity of carbohydrates stored therein, while the protein content diminishes." * * *

"It is not justifiable to speak of the size of the kernel and the protein content of the berry as 'race characters.' They may be such to a certain limited extent, but the influence of the race will in this connection be far exceeded by the influence of the climate and partly also by the soil and cultivation."

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The quotation continues to set forth the dependence of the character of the grain, i. e., whether it is starchy or rich in protein upon conditions of growth, especially upon weather conditions. It also discusses the effects of transferring a wheat, "endemic" to a given climate, to a different one, especially to a hotter and drier one. The application of this quotation seems to depend upon its bearing upon the relative quantities of protein and starch produced in the berry. The fundamental distinction between the flinty and yellow-berries is plainly considered to be their relative richness in protein or in starch. I do not understand from the quotation that the author, Schindler, had the yellow-berry condition specifically in mind but the relation of the protein content to that of the starch. This may be a part of the yellow-berry problem. It evidently is, but we may have high or low protein without our special affection of yellow-berry. Two different samples of the same variety of wheat, each equally free from yellow-berry, may vary quite as much in their protein content as two samples, one of which is affected with the yellow-berry and the other not. Still, it must be acknowledged, that the chief difference effected in the composition of the wheat is, so far as we know, precisely this, i. e., a lower protein and a higher starch content, but the physical characters of the kernels are very different from normal berries. There can be no doubt about Schindler's attaching great importance to the weather conditions, for he is quoted as saying:

"From these considerations it undisputably follows that even in one and the same locality and with the same variety, the relation between protein and starch must be a variable one according to the weather conditions, even though it is to be admitted that individual sorts or races, as the case may be, may possess for themselves an especially different energy of assimilation. It is certain, however, that this latter in its final effect stands far behind that of climate and of the weather."

There can be no doubt that the author intends to attribute a determinative influence upon the composition of wheat to the climatic factors whether he had the yellow-berry in mind or not. The authors, Roberts and Freeman, evidently consider the yellow-berry something more than an abnormal ratio between the protein and starch content of wheat, for they say that:

"The yellow-berry is a case of not merely a failure to form the normal amount of gluten but probably also of a corresponding failure on the part of the plant to compensate by a relative increase in the starch content."

It is not evident upon what they base this opinion, at least, I have found no definite data given except the nitrogen determinations made and given in the Nebraska Bulletin 89. I suppose that this judgment is based upon their knowledge of the physical prop-

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erties of the berries. These would appeal to most persons familiar with them as quite sufficient to justify the opinion expressed. But, whatever the composition and properties of these berries may have been, they (Roberts and Freeman) assume that climatic factors are, above all others, important in determining these and set themselves the task of finding out the critical period in the development of the grain, or that period when it is most susceptible to the action of those factors determining the yellow-berry. They experimented with winter wheat and consequently have two periods of growth, the autumn and spring periods. They find that the longer the autumnal period, especially with favorable conditions in the early part of the period, the higher the percentage of yellow-berry. In the season 1905-06, they found for wheat planted 28 September in moist soil 53.80 percent yellow-berry; for wheat planted 16 October in rather dry soil 19.58 percent yellow-berry. They find in these results, the two quoted are the extremes of a series, a relation between the length of the autumn growing period and the amount of yellow-berry produced. In 1906-07 they obtain results of the same significance; a difference of thirteen days in planting is followed by a difference of 12 percent in the yellow-berries. This difference was, as in the preceding year, in favor of the late planting, this giving the lower percentage of yellow-berry. They divided the spring into practically three periods, and studied the effect of the mean temperature and rainfall and also considered the whole of the spring growing period; so that they treated of the whole period from first heading to maturity, for three weeks before maturity, and for two weeks before maturity. I can do no better than to give their own words to state their results.

"If we attempt to interpret the effect of these combined influences in terms of the rapidity of growth of the plants and of the ripening of the grain, and to correlate them with the percentage production of yellow-berry, we shall find, as previously stated, that the prevalent idea that slow ripening is correlated with high percentages of yellow-berry is apparently justified by the data collected from our wheat cultures for 1906-07 when the total averages for the two years are compared. When, however, the data for the different varieties within a given season are considered, this rule does not hold. Now, since it is improbable that influences that would operate as between different seasons to bring about such a result would fail to operate in a given season, there must, therefore, be other factors which complicate the results, and which are not analyzable without taking into consideration data with reference not alone to climatological conditions but also to the hereditary tendencies of the varieties concerned."

These sentences state as clearly as can be stated the conclusion at which Roberts and Freeman arrived, though they subsequently,

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and perhaps concurrently, with the experiments on which this conclusion is based, made quite a series of experiments upon, "Individual and varietal inheritance of yellow-berry," the conclusion of which does not seem to be altogether satisfactory or decisive. Not being, perhaps, a competent judge, I will not venture to formulate a conclusion, but will again give the authors' own language.

"In view of the fact that but one head from each plant of the pedigree stocks had to furnish the grains on which an estimate of the percentage yield of yellow-berry in the plant as a whole was based, the result is really surprisingly confirmatory of our hypothesis that the yellow-berry is a 'tendency' which finds expression in certain strains or races more markedly than in others, and is heritable.

"In so far as this is the case, the yellow-berry problem is one which is capable of being handled by the breeder with a view to the propagation of pure strains of wheat which may be found free from the yellow-berry under all conditions. It, therefore seems reasonable to hope that from a group of pure strains of pedigree wheats producing no yellow-berry for two successive years—which we have—a race of wheat may be derived which will go entirely wide of this tendency to deterioration in the product."

I believe that this quotation presents the conclusion which the authors would have us draw from their results as clearly and fairly as they have anywhere stated it. One thing seems clear, that is, that while they admit that the weather influences the development of yellow-berry they sought throughout their work some specific cause for it and think that it is to be found in some inherent quality in the strain or race of wheat which may be strengthened by climatic conditions and the length of the growing season.

In 1913 Prof. H. L. Bolley of North Dakota returns to the subject in Bulletin 107 of that station entitled "Wheat; Soil Troubles and Seed Deterioration; Causes of Soil Sickness in Wheat Lands; Possible Methods of Control; Cropping Methods in Wheat." We are concerned only with what he says regarding the subject of yellow-berry. Prof. Bolley throughout this bulletin speaks of deteriorated wheat and seems to include under this term a variety of things which evidently may have different causes, for, as Prof. Bolley himself states, the problem is a complex one, but he gives us no clear analysis of the deterioration had in mind and appeals to diseases of the plant to account for deterioration in general. There is no doubt but that Prof. Bolley is entirely correct in maintaining that disease may cause the death of plants or curtail their productiveness, but he seems to attribute practically all deterioration to disease, or infestation of some kind, and to minimize the current teaching relative to the importance of those questions of food supply in the soil, generally had in mind when we speak of

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fertility. He seems to take exception to the stress laid, by chemists in particular, upon these questions, with which I have no quarrel, and it is not my intention, in this place at least, to take any exceptions to his views. This is in no way my purpose, but simply to give such quotations as may faithfully present his views upon the question forming the subject of this bulletin. Under the caption "Symptoms of Deterioration as noted in Soil and Seed," he uses the following language:

"The history of wheat cropping shows that at first new lands yield bounteously in quantity and quality, but in a comparatively few years an evident deterioration of the seed produced sets in. The fall in bushelage per acre is not more marked or more rapid than the deterioration in quality as to plumpness of grain, flour content, hardness, color and other characteristics. By almost common consent, many agriculturists, chemists, biologists, millers and farmers have assumed, when such conditions of the crop arise after more or less continuous cropping to wheat and other cereals, that the lands have 'deteriorated.' The symptoms as observed in the slow growth of the crop, the dying out of young plants, the blighting, 'tip-burning,' 'sun-scalding' and discoloration of the young plants, the weakness of the straw, the shrivelled seed, the common deficiency in proteid content of the grain have all been taken as indicating improper food relations."

"I think I am safe in saying that it has been quite commonly assumed that lost nitrogen, phosphate, lime or other plant food deficiencies are to be expected under such cropping conditions. Furthermore, chemists, as they measure availability of plant food, have found that such old soils often show more or less change in the available plant food. The writer, knowing as he does that a wheat plant can extract essentially all of the available material of a particular food element from the soil before showing noticeable change in its growth relations has always doubted that the general conclusions of soil deterioration under such cropping conditions is justifiable; for there are many fertile soils which fail to produce normal wheat, and there are some very poor, weak soils which produce nice, properly colored milling wheat. These, so-called, deteriorated wheat soils produce high yields and quality in other crops."

It is evident that the deterioration here had in mind includes plumpness of the grains, the flour that they will yield, their color and hardness. In the quotation given, and also in other portions of the bulletin, he plainly questions the correctness of the general assumption that there is a relation between the food supply in the soil and these conditions, especially that there has been a soil deterioration in this respect, or, as it is commonly expressed, in soil fertility. The author even goes further and asserts that the application of farmyard manure may even produce "disastrous results" in the nature of soft, overgrown straw and shrivelled, off-grade grain. His interpretation of this is that it shows that the land

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has not deteriorated. The author further strengthens his position by discussing new and virgin lands, still to be found in their wheat-growing sections, but I will quote his own words.

"New and virgin lands remaining in the wheat belt unplowed, even though they represent select areas of land, when plowed and sowed to wheat, under present conditions, cannot now as in early days be relied upon to produce the quality of wheat then produced on immediately adjacent lands. As often as otherwise the crop is apt to produce light weight, off-colored, 'spotted,' 'white-bellied,' 'black-pointed,' 'pie-bald,' shrivelled grain upon a rag-like, light weight straw. Because of these facts, many of our most able, old-time wheat growers have been inclined to contend that there must have occurred changes in climatic conditions. No one can have the hardihood to contend that these native lands, never before plowed, have only sufficient fertility to maintain the normal yield and quality of grain for but one or two years. These lands certainly are as fertile as the adjacent areas which were broken in the early days of wheat culture. It can be seen at a glance that these present new lands are now subject to wheat diseases coming through poor seed and by dust and dirt from the adjacent old worked wheat lands."

The cause of deterioration, as the author sees it, is here distinctly attributed to diseases coming through poor seed and by dust and dirt from the adjacent, old-worked, infected wheat lands. The deterioration consists in the kernels being of light weight, off-colored "black-pointed," "spotted," "pie-bald," "white-bellied," and shrivelled. This is on new or virgin land after one or two years. At least I so understand it, for he says that:

"No one can have the hardihood to contend that these native lands, never before plowed, have only sufficient fertility to maintain the normal yield and quality of grain for but one or two years."

In summarizing the symptoms on a subsequent page, he is quite as explicit and his statements are more general. He says:

"All complain of much straw and light grain, yet find, when the yield is reasonably high in bushels, the grade is off whether it is well harvested or not. This does not, as one might suspect, indicate lack of nitrates in soil, but rather the contrary; for this immature shrivelled grain is apt to have a comparatively high proteid content, its deficiency being chiefly the starch products. Grains are often found to be off-color, 'pie-bald,' 'blighted,' 'black-pointed,' also showing pink, brown, and other colorations of the berries even though there has been no moisture at harvest time. These peculiar, shrivelled and discolored grains we find to be internally attacked by fungi. The color is either due to the presence of the fungi or to changes caused by them."

Later the author explains the cause of young plants dying, ascribing this cause to genera of Fusarium and Colletotrichum. In so doing, he says:

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"Each of the various types of injured grains as pink-colored, black-pointed, white-bellied, etc., breed true, reproduce themselves. Certain conditions of soil, weather and variety, however, seem to largely affect the development of these features."

It is certainly difficult to reconcile the conclusion of the former publication of this station, North Dakota, with the statement just made, for in the conclusion drawn from previous work the same author says:

"From the results (of experiments made.—H.) the author believes that the white spots are not due to crossing nor are they matters of heredity, but that this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is yet in the chaff."

It is possible that the author had reason for changing his opinion before writing Bulletin 107, North Dakota Experiment Station. If so, he failed to state the reason or even to take any cognizance of the statements of the earlier bulletin. In a lecture delivered before the agricultural students of the University of Wisconsin, which appeared in Science, July, 1913, he maintains, or rather asserts, the findings of the later bulletin. The author may have an object, worthy and well advised in North Dakota, but it is not effective in shedding light upon the question that I have in hand, though he evidently includes the condition of yellow-berry as constituting a symptom of deterioration.

The four bulletins from which these statements have been given constitute about all of the literature to be found in our station publications touching upon yellow-berry.

I am not at all sure that the California bulletins on the wheats of California have this question in view at all. A white wheat is by no means a diseased wheat or an abnormal one, though at times it would seem almost as though they were really describing wheats which were so badly affected that every kernel was mealy or starchy. These wheats are spoken of by some as white, soft, starchy wheats. Dr. G. W. Shaw and A. J. Gaumnitz describe White Australian as follows:

"Grain large, long, plump, white, soft, opaque, starchy interior: Little Club, grain medium large, short, white, irregular in shape, very soft and starchy interior; Sonora, short, round, plump, white starchy interior."

It would be difficult to give a better description of kernels of our wheats wholly affected by yellow-berry. I may be mistaken, but I do not understand the California bulletins to deal with their wheat as diseased or deteriorated wheats, but that they consider these wheats as normally white, soft wheats. If they consider them abnormal wheats, diseased wheats, they assign no cause, and sug-

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gest no remedy and so far as the yellow-berry question is concerned, or better so far as our present discussion of the yellow-berry question is concerned, the Californian wheats may be neglected simply because the study of these wheats as presented in their bulletins is not parallel to the phase of our work presented in this bulletin. As stated, no better description of wheat kernels, wholly affected with yellow-berry, could be given than the descriptions of the various California wheats furnish,—large, white, plump, soft, opaque, starchy, —these are the only adjectives one could properly use in describing some samples of our Defiance, whereas for the description of other varieties, we could not use them truthfully at all. The Defiance kernel in its normal condition is a short, plump, light-amber colored, translucent, flinty kernel. Even the term soft, if used to express the ease with which the kernel may be crushed between the teeth, would apply to the abnormal, but not to the normal kernels of Defiance wheat. I think there is no reservation to be made in stating that a kernel wholly affected with yellow-berry is much softer than a normal, flinty berry of the same variety, and it is certainly very different in appearance.

There is a perfect agreement in the descriptions of yellow-berry given by the different authors so that there is no question but that they have written about the same condition. The best description is, perhaps, given by Roberts and Freeman. "By the term 'yellow-berry' is meant the appearance" (in wheat of a hard flinty grain), "of grains of a light yellow color, opaque, soft and starchy. These opaque yellow grains constituting what are called 'yellow-berries,' may have this character throughout, but sometimes from a small fraction to half of a grain will be yellow and starchy, while the remainder of the kernel will be hard, flinty and translucent."

It very often happens that the only imperfection in a kernel will be a sharply defined spot in one or the other half, or in both halves of the kernel; again the affection is more diffused and may involve one-half of the kernel or a streak along the back of the kernel. Owing to the fact that these spots and areas are less translucent than the surrounding flinty portion, often being quite opaque, the best manner of observing the kernels is by transmitted light. In this way it will be discovered that many kernels which by reflected light one would consider free from the affection, are in reality quite badly affected. When the berry is wholly affected its general color will be affected by the color of the bran or outer coating and will vary from dull white with a tinge of yellow, to yellow. Such kernels are usually, if not always, plump and when cut transversely, exhibit a white, starchy interior without any horny portion

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whatever. Such kernels are soft and starchy. If such kernels as show small yellow spots be cut through transversely, these spots will show in the section as white, mealy, or starchy circles imbedded in a horny, translucent matrix. (See inserted Plate).

The plate needs but little explanation. It represents six varieties of wheat, three spring and three winter. The top row in each case represents normal flinty berries, the second row mildly affected berries and the bottom row badly affected berries.

While authors are agreed, so far as they attempt to describe the appearance of yellow-berry, they are not agreed as to its cause. Two different causes are assigned for it in North Dakota bulletins. In the one first published, the cause was stated definitely to be the action of moisture, air and sun upon the berries while still in the chaff. Prof. Bolley, the author, said:

"From the results the author believes that the white spots are not due to crossing, nor are they matters of heredity, but that this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is yet in the chaff. If the weather action is long continued, the grains become evenly bleached over the entire surface. The color and hardness of the grain can be maintained by proper care in harvesting and curing."

This statement is definite in regard to both cause and remedy.

In Nebraska Bul. 89, we have essentially the same conclusion:

"The chief cause of this condition is allowing wheat to become overripe and failure to stack the sheaves. 'Yellow-berries' as compared with hard, red ones have a lower gluten content and are lighter in weight."

The authors of the Kansas bulletin 156, do not agree with these views for they state definitely:

"It should be further emphasized that the bleached, opaque grains due to weathering are not yellow-berries. In weathered kernels the grain has an opaque and rather dirty, grayish yellow aspect, which appearance affects the grading of the grain adversely, but is not necessarily associated with an inferior condition of the kernel, although such is frequently the result of exposure to the weather."

This statement is not in accord with the statements of the two bulletins previously quoted. The Nebraska bulletin gives the actual increase in yellow-berry produced by exposure. I assume, as there is no statement to the contrary, that Lyon and Keyser sorted their kernels in reflected and not transmitted light and in this way failed to count many affected kernels in the protected wheat which would have become easily recognized on bleaching the grain. In other words, I think that the yellow-berry was rendered more easily recognized, more evident, by the bleaching, but not caused by it. There is, however, a fact which would appear to

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support the assumption of an increase after cutting, i. e., that the deposition of starch may continue for a time after cutting at the expense of material accumulated in the plant, but this would seem to apply to the protected as well as to the exposed wheat.

After having written the above, I received a note from Prof. Keyser, a portion of which pertains to this subject and reads as follows:

"It is stated in Bulletin 89 of the Nebraska Experiment Station that exposure to weather conditions, increases the amount of yellow-berry present in the grain. I think, perhaps, in view of a fuller experience with yellow-berry, that a slightly different statement of the facts observed would come more nearly to stating what actually took place. The bulletin states that exposure increased the yellow-berry. What actually occurred seems to be, that exposure increased the readiness with which yellow-berry present was detected. In other words, exposure enabled us to see yellow-berry in cases where it was not visible in the bright, freshly thrashed, or freshly harvested grain. In other words, exposure enabled us to detect yellow-berry in those cases which were on or near the boundary line of yellow-berry and clear, corneous grain."

This leaves no doubt in my mind but that the apparent increase of the yellow-berry on exposure to the weather, was due not to the formation of the yellow spots in the grain, but that the effect of the bleaching was simply to reveal yellow-berry in many kernels in which it was not readily detected in their fresh, unbleached condition. The continued deposition of starch after cutting, especially of grain not fully ripe, remains a possibility.

The Kansas bulletin goes further and states:

"The yellow-berry then appears to be distinctly a physiological growth product due to certain conditions thus far not clearly analyzed or satisfactorily explained."

After having studied the problem, in apparently all of its physiological phases, the conclusion of these investigators, Roberts and Freeman, is succinctly given in these words:

"In view of the fact that but one head from each plant of the pedigree stock had to furnish the grains on which an estimate of the percentage yield of yellow-berry in the plant as a whole was based, the result is really surprisingly confirmatory of our hypothesis that the yellow-berry is a 'tendency' which finds expression in certain strains or races more markedly than in others and is heritable."

This statement is the nearest approach to a formulated conclusion, embodying the results of their extended experiments that I have found. This conclusion is positively opposed to that arrived at by Prof. Bolley in the Annual Report of the North Dakota Station for 1904, in which he states:

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"That the white spots are not due to crossing, nor are they matters of heredity, but this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is still in the chaff."

Prof. Bolley himself practically repudiates the conclusion here stated, especially in regard to the direct cause of the affection, in North Dakota Bulletin 107, and again in a lecture given before the agricultural students of the University of Wisconsin and published in Science, July, 1913. Prof. Bolley in discussing the deterioration of wheat makes the following statements bearing upon the causes of it:

"All complain of much straw and light grain, yet find, when the yield is reasonably high in bushels, the grade is off whether it is well harvested or not. This does not, as one might suspect, indicate lack of nitrates in soil, but rather the contrary, for this immature shrivelled grain is apt to have comparatively high proteid content, its deficiency being chiefly the starch products. Grains are often found to be off-color, 'pie-bald,' 'blighted,' 'black-pointed,' also showing pink, brown and other colorations of berries even though there has been no moisture at harvest time. These peculiar, shrivelled and discolored grains we find to be internally attacked by fungi. The color is either due to the presence of fungi or to changes caused by them."

Again he says:

"Each of the various types of injured grains as pink colored, 'black-pointed,' 'white-bellied,' etc., breed true, reproduce themselves."

It is evident from these passages and others given, that Prof. Bolley now holds the "pie-bald", "yellow or white bellied", condition to be due to the action of fungi. He puts these yellow-berries in the same class with black-pointed berries, with pink or brown colored berries, and assumes that they all have the same cause, namely fungi. Concerning the black-pointed berries he is certainly correct and also in regard to the pink and brown berries alluded to, but he includes the spotted and yellow-berries with these, which is wrong. This presents the subject as treated of in our American literature so far as the stations are concerned. The United States Department of Agriculture has given a full statement, a fair reproduction, of Kansas Bulletin 156 in one of its accounts of station work. This is a matter of the distribution of the results of station work, so I have not mentioned it.

As I have before intimated, I am not sure but that all of the work of the California Station on the white wheats do not deal with yellow-berry, but Dr. Shaw and his collaborators have confined themselves to a study of the wheats as they grow and not to the question of why they are mealy or starchy.

I have some samples of Idaho wheats which are very white and starchy, in fact, I can see no distinction between the physical

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properties of these samples and some samples of Colorado wheats which I fear must be acknowledged to present samples of wheat badly affected by yellow-berry. As I think many of our wheat growers will be interested, I will state these cases a little more fully. Our Colorado Defiance, a spring wheat, is normally a medium-amber colored wheat with a rather short, plump, flinty kernel. I have a number of samples of this wheat every kernel of which is almost white, wholly opaque, and has a dead, porous appearance, and when broken between the teeth simply crushes down and does not break with any life, and creates a sensation of mealiness on the tongue. When such kernels are cut they appear to be a mass of starch. Such samples scarcely bear any resemblance at all to normal Defiance wheat. I have samples of Red Chaff of which this is true in a very high degree. I have also seen just as extreme cases in kernels of Turkey Red and Kubanka. While I have samples of Turkey Red in which it is difficult to find a single kernel that is not affected, I have no samples of either Turkey Red or of Kubanka as bad as the Defiance and Red Chaff samples described. I have samples of Dicklow Spring wheat from Idaho which, if possible, are even worse than our Colorado samples of Defiance and Red Chaff. The kernels of these samples are plump, white, opaque, soft and starchy. I also have samples of Marquis grown in Idaho and also elsewhere in which it is very difficult, if not quite impossible, to find any kernels entirely free from the affection. It is for such reasons that I am convinced that if we find the cause of yellow-berry we will find at the same time the cause for the whiteness, opaqueness, starchiness and softness of all of the western wheats whether they grow in Colorado or in California.

In this place it should be emphasized that under yellow-berry is understood a condition indicated by yellow or white spots which may involve the whole kernel, with a greater or less degree of opacity, starchiness and softness. *There may be soft wheats which do not show this condition at all, but this softness is another thing which is distinct from the softness of these kernels.* Our Colorado Defiance is a softer wheat than the Red Fife, whether it should be classed as a soft wheat or not, is not my purpose to decide, but even in its best condition, it is a softer wheat than some others. It is not in this sense that we use the term soft as applied to these yellow-berry wheats. When we speak of softness due to yellow-berry, we mean that they are yellow or white, opaque, starchy and easily crushed; more easily crushed than flinty berries of the same variety of wheat grown under the same conditions.

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I am strengthened in my surmise that the Californian wheats belong to this class of yellow-berry wheats by the description of Californian wheats given by Mr. Henry F. Blanchard in Bulletin 178 of the Bureau of Plant Industry, U. S. Department of Agriculture, in which he describes thirty-six varieties, all of which are characterized as spotted or starchy. In this description as well as in that given by Dr. Shaw and Mr. Gaumnitz, we are strongly reminded of our yellow-berry.

I have mentioned this for no other reason than to suggest that the condition of yellow-berry is not a local phenomenon to be explained by some local condition of climate, coastal or continental.

There is ample evidence in the literature of wheat that this condition is neither new nor confined to this country. This is true even after we make allowance for possible misapprehensions due to accidental coincidences in description. Reference has already been made to mention of starchy berries as early as 1870. In 1904 we find starchy berries mentioned by H. von Feilitzen in Jour. Landw., also by F. Moertlbauer., Ills. Landw. It is further mentioned by Dr. Thomas Kosutany in his work on Hungarian wheats and flour, Der Ungarische Weizen und das Ungarishe Mehl, printed in 1907. In discussing the quality of wheat produced on large estates, and that produced on small estates, and by the peasant farmer, he says:

"I take the weight per hectolitre, the weight per 1,000 kernels and the degree of mealiness, together with the protein and gluten content into consideration in making the comparison."

Dr. Kosutany again refers to this subject in discussing the effects of the weather. After stating that very significant variations in the gluten content of grains were to be attributed to the weather conditions, he explains that the weight of 1,000 kernels of the weaker wheats is greater than that of 1,000 kernels of the strongest wheats, which he also considers as an effect of the weather conditions. He adds:

"The mealiness in the weaker wheats is 36.78 per cent; in the better wheats 23.25 per cent, from which it follows that the protein-rich wheats are altogether the glassier which is intimately connected with that which I have already discussed and considered necessary to mention in connection with the weight per 1,000 kernels."

The occurrence of starchy and spotted kernels is evidently very common in the Hungarian wheats. Dr. Kosutany gives the record of mealy kernels in the harvests of seven years, for 1890, and from 1899 to 1905. Out of eighty-three samples given in the harvest of 1890 there is only one sample entirely free from mealy or half-mealy, starchy or spotted kernels, and only 24 out of the

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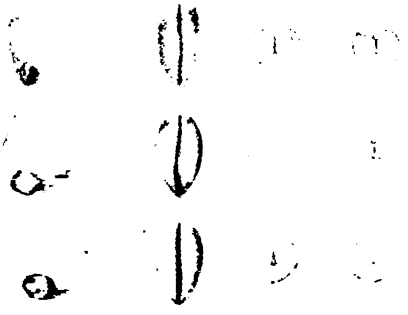
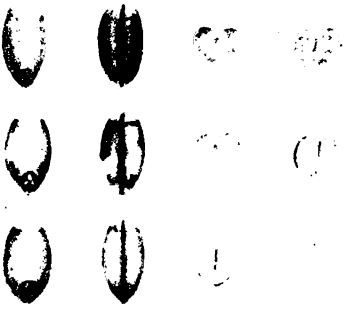
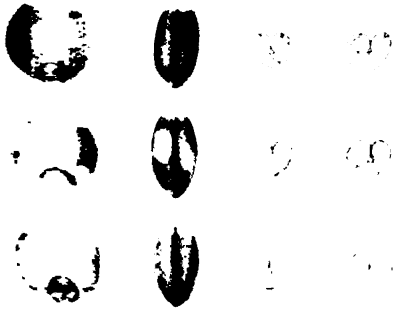


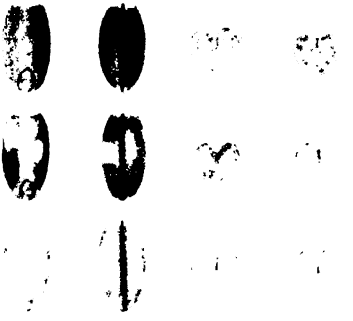
Kubanka



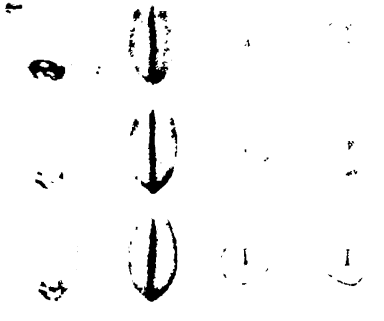
Turkey Red



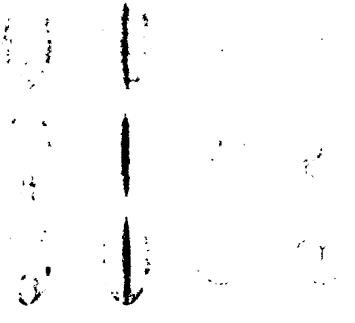
Red Fife



Kharkov



Defiance



Prize Taker

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remaining 82 samples that contain less than 15 percent of affected kernels. In the harvest of 1899, 38 samples, the average number of glassy, flinty kernels was 51.4 percent (Max. 78, Min. 9), of mealy kernels 16.3 percent (Max. 64, Min. 2), of half mealy, 32.5 percent (Max. 45, Min. 19); harvest of 1900, 53 samples, average mealiness 41.86 percent; 1901, 53 samples, 24.56 percent; 1902, average mealiness 44.85 percent; 1903, average mealiness 33.71 percent; 1904, average mealiness 24.09 percent, and in 1905, 26.08 percent mealiness. There were some samples in each year entirely free from this affection; in 1904 nine of the fifty-three samples, or 17 percent, were entirely free from affected berries. This affection is also mentioned as occurring in Roumanian wheat. Thirty samples are given for each of the three years, 1900, 1901 and 1902. The average of affected kernels for the three years is slightly over 91 percent.

These data will certainly suffice to indicate that "yellow-berry" has a very wide distribution whether this condition is identical with the starchiness of the Pacific coast wheat and all due to the same cause, which I think is the case, or not. That the same cause is operative in all cases seems probable, whether it is in Roumania, California or Colorado.

It seems to be customary to consider this mealiness as necessarily a sign of deterioration. I am not prepared to accept this view unreservedly. The term deteriorated wheat may at times be used advisedly, but it is very often used in a very loose, and in so general a signification as to mean nothing to the reader. The Pacific coast wheats are considered soft, weak wheats, this may be true and still it may be a question whether the starchy character of the wheat is indicative of deterioration. The Hungarian wheats are certainly considered among the very strongest wheats to be obtained and yet starchy and spotted berries make up a very considerable percentage of the average crop, in some few cases constituting the whole of some of the individual crops. Dr. Kosutany stoutly maintains that the Hungarian wheats have not deteriorated, though such claim has been made. It seems to me very probable that they may always have had starchy and spotted kernels in their wheat, but this does not necessarily follow from anything that is stated. Whether starchy kernels are necessarily kernels of inferior quality or not, I do not know. It is evident that millers object to them and, at least, the more advanced of these millers base their judgment upon the result of baking tests so it seems that the quality of the gluten must be inferior. Its quantity in slightly affected kernels is not necessarily low; on the contrary, it may be nearly or quite as high as in wheats of high quality.

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In badly affected kernels I do not think that there can be any question but that the total nitrogen and the washed gluten are lower than in flinty kernels grown under apparently identical conditions of soil and weather. This question, however, is entirely beyond the purpose of the present bulletin.

Concerning the cause of mealiness in the Hungarian wheats, Dr. Kosutany makes no explicit statements, incidentally, however, he does, but considers it with other qualities of the wheat. In discussing the qualities of wheat produced upon larger estates compared with such as is produced by small growers, he says:

"Judged by the determination of the degree of mealiness, the balance swings likewise in favor of the large land-owner and more thorough soil culture, which at first sight is surprising, for if the small owner's wheat is smaller grained, then according to the theory which we have proposed it should not only be protein-richer but also more glassy, because the wheat plant with shallow culture ends its assimilative activity earlier and therefore should contain less starch and more gluten in its kernels, which must be characterized by a greater glassiness. That this is not so can only be explained by this, that the fields in the smaller estates were not sufficiently manured and the wheat plants were not supplied with a sufficiency of nitrogen by the soils to form therefrom the protein corresponding to the (other) conditions. Furthermore, it is possible that a less advantageous rotation plays a part in it, in that the small owner has planted his wheat after a plant (crop) that has exhausted the available nitrogen of the soil so that the wheat grown after it, even with an ordinary manuring, must be relatively low in its nitrogen content."

The conclusion here stated in reference to the cause of mealiness is at variance with the opinions previously given. The previous views have disregarded the soil as a possible cause of starchiness or have dragged it in in the most incidental manner, apparently for the purpose of conceding that the soil has some influence, but the manner of statement always carries with it the intimation that the soil is at best a minor factor.

One of the tasks that Dr. Kosutany has set himself is to show that the Hungarian wheats have not deteriorated. I understand him to adopt the evidently correct view that mealy kernels are apt to be lower in proteins than flinty kernels and that a wheat rich in protein is probably better than one poorer in protein. With these views in mind his statements in the following quotations are readily understood. These statements are made near the close of his discussion of the relative desirability of wheat grown on large, well cultivated and fertilized estates and on smaller ones:

"I can, therefore, emphatically assert that the statement of those who claim to find the reason for the decreasing gluten content of (our) wheat in the intensive cultivation is erroneous and on the contrary it can

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be declared as a principle that through more careful soil-culture, heavier manuring, etc., not only more wheat can be grown upon the respective wheat-soils but (wheat) richer in gluten and for this reason better and more valuable. The statement that the quality, that is, protein-gluten content, of the wheat diminished with increased harvests has ceased to be valid as a rule. Cases may occur, as follows from the above (reference is here made to the results of experiments.—H.) that we can, by means of manures, especially slowly acting nitrogenous manures, and cultivation, within certain limits, not only increase the yield of wheat, but also increase its value which is closely related to its protein—respectively, gluten content.

"A proof of this is furnished by mills with an extended experience which place a higher value upon the wheat from the larger estates, provided the seed has not come from foreign lands, than upon the peasant's wheat; further, (by the fact) that in certain sections of the country, particularly in Banat, the quality of the wheat has actually deteriorated in consequence of the exhaustion of the soil, of ill-advised rotation of crops, of poor cultivation, etc., whereas the quality in other sections * * * according to the mills has increased in consequence of more careful cultivation and manuring."

Our own observations of the occurrence and cause of the yellow-berry are, so far as they are parallel, in harmony with those of Dr. Kosutany. Our observations now extend over two years and involve seventy-two experiments with field observations in other sections of the state, together with twenty-four samples from another state.

I do not think that there can be any question of the identity of the affection of our wheat with that of Kansas, Nebraska or North Dakota, and *almost no question but that the starchy, opaque wheats of California, and the Pacific coast states, in general, are identical in their character with extreme cases of yellow-berry in Colorado and have the same cause.*

In 1913 we had twelve plots of one-tenth acre each, i. e., four plots of each of three varieties. These plots were not planted for the purpose of studying yellow-berry, but yellow-berry developed very plentifully in some plots and not in others. In 1914 the experiments were repeated, no change whatever being made in the experiments, the same variety being planted on each set of plots and the individual plots received the same treatment. Owing to force of circumstances which no one could change, the ground was plowed in the Spring of 1913 instead of in the Fall of 1912. The land was turned to a depth of 12 inches and sub-soiled to a depth of 16 inches. These statements will suffice to indicate our purpose to give the ground a thorough cultivating. It is scarcely necessary to give further details of the cultivation in this connection.

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The varieties used in our experiments were all spring wheats. Defiance, a variety originated at this station thirty-odd years ago: Red Fife, seed obtained from South Dakota Experiment Station: Kubanka, seed also obtained from South Dakota Experiment Station.

In 1913 the plots were all sowed on 25 and 26 of April. The Fife was harvested on 6 August, 103 days from planting. The Kubanka was harvested 13 August and the Defiance on 14 August, or 110 and 111 days respectively, from the date of planting. The period of vegetation was short and the ripening took place in clear warm weather. The soil was quite dry, ten of the twelve plots which we shall discuss had received but little, so good as no water, since 12 June. All of the wheat was threshed on 21 and 22 August without having so much moisture as a heavy dew fall upon it after cutting.

In 1914 all plots were sowed on the afternoon of 6 and morning of 7 April, and harvested 6, 7 and 8 August. Fife was rather over-ripe. All of the plots were cut 122 or 123 days from planting. The irrigating water applied was one foot on all except plots 4 and 8, which received two irrigations, amounting to one and one-half acre-feet. In these statements I am making no note of a few hundredths of a foot either way. For our present purposes we omit the rainfall during the vegetative period. It may, however, be taken as six inches per year for the two years. This is very nearly correct. The time and manner of rainfall is of much more consequence to us than the amount that we usually have. We threshed all of the lots on 21 and 22 August. So far as the harvesting and threshing of these wheats are concerned the weather conditions were perfect. The Fife was unfortunately ripe enough to shatter a little but had stood not more than two days longer than was desirable. While the Defiance and Kubanka are normally about eight to ten days later in maturing than the Fife, they were not more than one or two days later than this variety in 1914. This abnormally early ripening was due to a shower that fell, 28 July, accompanied by some wind. The shower was of short duration but violent. It beat these varieties down rather badly, the leaves and stems, especially on some of the plots of Defiance, rusted and the crop was very materially injured. The same was true of the Kubanka but not to the same extent as of the Defiance. The Fife was scarcely injured at all by this shower because it was somewhat nearer maturity.

In order to facilitate the understanding of the experiments I add a plan of the experiments and the results obtained in 1913 on the plots considered in this bulletin.

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EXPERIMENTAL WHEAT PLOTS, 1913.

1. DEFIANCE
   Nitrogen, 80 lbs. per acre in two applications.
   Yellow-berry, none.

2. DEFIANCE
   Soluble phosphorus, 40 lbs. per acre. One application.
   Yellow-berry, 10 percent.

3. DEFIANCE
   Potassium, 150 lbs. per acre, one application.
   Yellow-berry, 30 percent.

4. DEFIANCE
   Check. Yellow-berry, 24 percent.

5. RED FIFE
   Nitrogen, 80 lbs. per acre in two applications.
   Yellow-berry, none.

6. RED FIFE
   Soluble phosphorus, 40 lbs. per acre, one application.
   Yellow-berry, 24 percent.

7. RED FIFE
   Potassium, 150 lbs. per acre, one application.
   Yellow-berry, 42 percent.

8. RED FIFE
   Check. Yellow-berry, 31 per cent.

9. KUBANKA
   Nitrogen, 80 lbs. per acre.
   Yellow-berry, none.

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10. KUBANKA
Soluble phosphorus, 40 lbs. per acre.
Yellow-berry, 35 percent.

11. KUBANKA
Potassium, 150 lbs. per acre.
Yellow-berry, 37 percent.

12. KUBANKA
Check. Yellow-berry, 31 percent.

The above diagram is self explanatory. The grains used were Defiance, Red Fife and Kubanka; the fertilizers were nitrogen, phosphorus, and potassium.

The percentages of yellow-berry obtained are indicated on each plot. Note the variations in each variety, depending upon the kinds and proportions of fertilizers used.

While we made thirty-six experiments in each of the years we will consider only twelve plots for three reasons: First, it will shorten the statement of our data; Second, the other twenty-four sets of data would simply confirm the twelve sets which we give, and, Third, I do not wish to anticipate, any further than is necessary for my present purpose, the data bearing upon the principal object of the real project in hand, which is not to discover the cause and prevention of yellow-berry in wheat, *though this may be the most far-reaching and practical result which I shall obtain.*

The land used in these experiments has been cropped continuously for six years without fertilization. It is now seven years since it was in alfalfa. The soil proper varies from eight to twelve inches in depth. While the subsoil is a little richer in lime salts, it differs less from the soil above it than is usually the case. This subsoil is capable of forming a very desirable soil when brought to the surface, aerated and permitted to become enriched in nitrogen. Only the principal features of the composition of this soil and subsoil is given, but these are sufficient for our purpose, namely, to give as correct an account of our conditions as is possible; for this purpose the amounts of phosphoric acid, potash and nitrogen are all that we deem necessary.

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MAIN FEATURES IN COMPOSITION OF SOIL AND SUBSOIL.

	Soil		Subsoil	
	Agricultural Analysis Percent.	Mass Analysis Percent.	Agricultural Analysis Percent.	Mass Analysis Percent.
Phosphoric Acid	0.175	0.217	0.160	0.185
Potash (Potassic oxid)	0.715	2.475	0.573	2.607
Total Nitrogen	0.143	....	0.060	....
Citric acid soluble.				
Phosphoric acid	0.021		0.015	
Potash (Potassic oxid)	0.036		0.018	
One-fifth normal nitric acid soluble.				
Phosphoric acid	0.066		0.073	
Potash (Potassic oxid)	0.057		0.020	
Portion of soil soluble in water	0.388		0.345	

The last determination, the portion of the soil soluble in water, is given because I believe that this is an important factor in the agriculture of the semiarid regions. To some, the figures 0.388 and 0.345 may convey only a slight notion of the mass of salts involved. The samples of soil and subsoil together were taken to a depth of a little more than one and three-quarters feet, but the wheat plant under favorable conditions sends its roots down to a distance of more than twice this depth. The amount of water soluble material in the soil represented by our samples amounts to 3,670 pounds as the average for each million pounds of soil, which gives us from 12 to 13 tons of soluble salts per acre taken to this depth of one and three-quarters feet. While the salts actually dissolved out of this soil by the water may not be capable of acting as plant foods, it seems improbable that they are indifferent or take no part in the changes which are constantly going on in the soil. Our theory for instance of the action of lime includes its ability to liberate potassium salts, likewise it is believed that soda salts may in some cases also act to make the potassium which may be too firmly held to be readily taken up by the plants, more available and in this way exercise a beneficial action on the growing crop. If these views be correct it would seem probable that this large amount of soluble salts may constitute an important factor in the question of the fertility of the soil.

The supply of the plant foods which it is usually considered necessary to take into account is ample in this soil to produce abundant crops. This is not a matter of theory, but of fact. It would be very bad for the theory if it indicated a contrary conclusion, for this soil will yield from 30 to 40 bushels of wheat without the application of manures of any kind, chemical or farmyard.

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The experiments mentioned were made in sets of three and a check. Inasmuch as we used three varieties we have a series of twelve experiments on each of three sections of land. In this place I will give the results from one section only, but I will give the results for two years, in which we have wheat after wheat. The varieties used were, as stated, Defiance, Red Fife and Kubanka. I applied liberally each of the desirable elements, nitrogen, phosphorus and potassium, singly but not in combination. My reason for doing this has nothing to do with the object of this bulletin. I have stated the quantities applied but I wish to divorce the subject of yellow-berry from all questions of yield and quality in so far as I possibly can. I will give the yield and weight per bushel for the two years to remove any impression of exhausted soil or unfavorable cultural conditions.

YIELD AND WEIGHT PER BUSHEL, CROPS OF 1913 AND 1914.

			1913		1914	
Variety	Designation of plot	Area of plot	Bushels per acre	Wt. lbs. per bu.	Bu. per acre	Wt. lbs. per bushel
Defiance	Nitrogen Plot.....	1-10 acre	42	60	29	56
	Phosphorus Plot.....	1-10 acre	40	62	39	58½
	Potassium Plot.....	1-10 acre	43	62	37	59½
	Check Plot.....	1-10 acre	38	62½	33	56
Red Fife	Nitrogen Plot.....	1-10 acre	39	63	52	64¼
	Phosphorus Plot.....	1-10 acre	33	63½	45	63½
	Potassium Plot.....	1-10 acre	33	63½	44	64¼
	Check Plot.....	1-10 acre	31	63½	43	63¾
Kubanka	Nitrogen Plot.....	1-10 acre	39	63	49	64½
	Phosphorus Plot.....	1-10 acre	38	64½	47	65
	Potassium Plot.....	1-10 acre	37	64¾	45	65
	Check Plot.....	1-10 acre	36	63½	43	65

These yields including the Fife check 1913, and all of the Defiance plots for 1914, give no hint of exhausted soil and only by comparison with the yields of the other plots do they hint of any unfavorable conditions.

Some of these wheats are badly affected with yellow-berry and the most of them, almost all of them in fact, are affected in some degree. The only other affections at all noticeable in these samples are now and then a berry discolored brown and a few black-ended berries. The black-ended and brown berries are due to infection by fungi. The number of such berries was not greater in 1914 than in 1913, though I used the crop of 1913 for seed in 1914 and used the same plots for the respective varieties. Neither the seed nor the soil was treated in any manner. This is simply a statement of

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fact. It is not intended to commend this procedure, but we had little or no reason to treat our seeds. The only reason that we would have had for treating it would have been to combat the Altenaria which is the principal cause of our black-pointed berries, and the ordinary treatment usually given seed grain is of little or no value in this case. There is no question but that the soil may become seriously infected with fungi injurious to crops and all reasonable means should be used to prevent or correct such a condition, but our grain is not injured by fungi.

As already stated, the weather conditions during the growing period of these crops were favorable, only one unfortunate feature appearing in the two seasons. This was a violent shower on 28 July 1914; this shower was of short duration but did considerable injury to my crop. The only question which concerns us in regard to this injury is, did it play any part in the production of the yellow-berry? This question can be answered in the negative, especially if we consider the question to refer to the cause of this affection. The reason is conclusive, because the yellow-berry had already appeared in the wheat, that is in some of it, before this, besides in 1913 we had perfect weather conditions and we had yellow-berry, not so badly as in 1914, but badly enough to give a definite, negative answer to the question suggested in this connection.

The only causes, heretofore, assigned for the appearance of this affection in wheat are over-ripeness of the wheat, standing too long in shock, exposure to the action of moisture, air and sunshine, a heritable "tendency", the action of fungi, and climatic and weather conditions,—no one of which can be considered as the cause in our case. In 1913 the wheat was cut just as soon as we considered it safe to do so, and likewise in 1914, except that the Fife was a day or two earlier than the Kubanka and Defiance, and they were cut on the same day. The wheat was allowed to stand in shock not more than twelve days either year and no rain beyond a trace, less than four-hundredths of an inch during the twelve days, fell upon it, so we considered over-ripeness or late cutting and exposure after cutting as sufficiently answered by the elimination of both, besides the yellow-berry appeared in the most pronounced fashion while the berries were still green. That adverse climatic conditions had nothing to do with it, is evident from the record, for we had clear, warm, dry weather conditions for the whole growing periods of the two years, with the slight exception already mentioned.

We have no proof at all of any fungous trouble with either the wheat or the plants other than that already mentioned which is not significant and has no relation at all to the yellow-berry.

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The two things are entirely distinct. We have flinty berries, wholly unobjectionable in any respect except that of having a blackened end, we also have spotted or yellow-berries both with and without such ends. The blackened ends are due to fungi; this fact is quite easily established by placing the black-ended berries in a culture dish under proper conditions when an abundant growth of the fungus affecting the berry will be obtained. Simple cases of yellow-berry do not afford this proof of fungous affection.

The question of a "tendency" which is heritable is fully set aside by the fact that we can, from the same lot of seed, under identical conditions of climate, grow crops affected with or free from yellow-berry.

Furthermore, the question is not one of the total supply of plant food. I have given the yields per acre for two succeeding years for the same varieties of wheat planted on the same sections of ground, every fourth one of which is a check plot. The minimum crop on any check plot for the two years is 31 bushels per acre, with the wheat weighing 63½ pounds per bushel. The same plot the succeeding year, without the application of any fertilizer and planted to the lowest yielding variety experimented with, yielded 43 bushels, weighing 63¾ pounds per bushel. This yield and weight per bushel does not indicate any deficiency of fertility and yet this wheat is badly affected with yellow-berry. I deem it altogether justifiable to conclude that yellow-berry is not a matter of total available plant food in the soil. It is no more a matter of starvation than of fungous trouble, which has nothing whatever to do with it, nor of a total excessive supply, but evidently a question of the ratio in which these food elements are present. In our case it is evidently the ratio between the potassium and nitrogen which determines the absence or presence of yellow-berry. I am satisfied that this is the cause of our yellow-berry and believe that the explanation is applicable to all cases. We have red wheats from some sections of Colorado which are white and mealy or starchy. These samples are as white and as mealy as any white wheat that I have seen. We have all degrees of this affection from a single, minute, yellow spot set in a flinty mass to the degree just designated in which the whole kernel is mealy. The cause of this is the one just stated, the ratio of the available potassium to the available nitrogen.

While it is possible that mealy wheat grown in Idaho or California might owe its mealiness or starchiness to some other cause, I hold it as quite certain that this is not the case, but that it is due to the fact that in these soils the ratio of available potassium to the available nitrogen is too high. There may be, as in our case

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there is, as shown by the yield of the check plots, an ample supply of nitrogen to grow bountiful crops, 38 and 33, 31 and 43, and 36 and 43 bushels for the checks with different varieties for the respective years, but the degree of mealiness or starchiness, the yellow-berry, in the wheat depends upon the relative available supply of these two elements.

The object of this bulletin is to show this cause and to offer some suggestions regarding the prevention of yellow-berry, and not to discuss the quality of the wheat. This feature is reserved for presentation with further results of our study which may not appear for some time. This much may, however, be stated at this time. The composition of the wheat, whether it involves quality or not, is profoundly affected. This result is independent of "climatic conditions." What modifying influence "climatic conditions" may exercise I will not at this time attempt to discuss, but it is subordinate, so far as yellow-berry and its effects are concerned, to the influence of the soil,—in this case, specifically to the potassium-nitrogen ratio.

The record of yellow-berry for the two years 1913 and 1914 on the twelve plots taken into consideration in this bulletin is given below, together with the record of "black-pointed" berries for 1913.

PERCENTAGE OF YELLOW-BERRY IN CROPS OF 1913 AND 1914.

		1913	1914	
Variety	Fertilizer	Black-pointed berries percent	Yellow-berries percent	Yellow-berries percent
Defiance	Nitrogen	6.7	none	none
	Phosphorus	12.9	10.0	50.0
	Potassium	15.3	30.0	63.0
	Check	13.0	24.0	36.0
Red Fife	Nitrogen	2.0	none	24.0
	Phosphorus	5.0	24.0	97.0
	Potassium	5.0	42.0	98.0
	Check	5.0	31.0	98.0
Kubanka	Nitrogen	5.0	none	23.0
	Phosphorus	12.6	35.0	94.0
	Potassium	9.5	37.0	96.0
	Check	16.0	31	97.0
	Results observed in field culture			
Turkey Red	Land affected by nitre			25.0
	Land not affected by nitre			100.0

The statement of these results in percentages of spotted and yellow-berries conveys no adequate notion of the differences noticeable between these samples. The potassium not only increased the

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number of yellow-berries, but imparted to the grains grown with its application a fullness of form and a paleness or deadness of color that are very marked, together with the appearance of mealiness or opacity.

We see that, in every case, the application of nitrogen which was in the form of sodic nitrate, greatly reduced the amount of yellow-berry, in some cases even preventing it altogether.

To my mind the two samples representing actual field conditions in another portion of the state are more interesting than any of my experiments, for in the one we have the natural, if I may use the term, development of nitrates in the soil, and in the other we have the ordinary cultural conditions obtaining on a farm well kept by a thrifty owner. In the one we have seventy-five percent of the berries translucent or entirely free from yellow-berry, in the other we have none entirely free, but nearly all badly affected. These grains are so different that the manager of the local mill stated that they spoke of such samples as constituting different varieties. In fact, this manager himself spoke of them as distinct varieties, and this too, in spite of the fact that he knew that the same lot of seed, Turkey Red, had been distributed to these parties.

These facts pertaining to the effects of the nitrate are entirely consonant with observations already on record. H. von Feilitzen, (Abs. Expt. Sta. Record, Vol. XVII, p. 24) says:

"Two years' experiments on four different kinds of soils show that glassy, hard kernels of spring wheat or barley are richer in protein than those of a mealy consistency.

"Glassiness or mealiness in the seed produced no effect upon the yield and size of the kernel, but apparently exerted a slight effect upon the glassiness or mealiness of the grain. The proportion of glassy kernels was found to be greater and the protein of the grain was higher, as a rule, on moor soil than on soil of mineral origin. The climatic conditions are considered as producing a marked effect on the quality of the grain. Nitrogenous fertilizers in general, increased the percentage of glassy kernels."

Also F. Moertlbauer (Abs. Exp. Sta. Record, Vol. XXV. p. 334) says:

"Very early applications (of sodic nitrate) on winter wheat decreased the flintiness of the kernels, late applications increased it. In every case where a part was applied late the hardness was improved. A top dressing when the heads began to form invariably produced a marked increase in the flintiness. * * * The protein content varied with the flintiness. The correlation was not a close one. Flintiness is not the only condition which determines the protein content."

These are the most direct and definite statements that I have found bearing upon the effect of the available plant food upon the

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prevalence of yellow-berry, the observation of Feilitzen that moor soils which are usually low in potassium produce a larger proportion of flinty berries than mineral soils, is suggestive of the views presented in this bulletin. The quotations from Dr. Kosutany have a similar significance but are not so explicit.

I have carefully avoided any discussion of the differences in the composition and quality of flinty and yellow-berries in this bulletin as being beyond its purpose. These subjects will be dealt with in a subsequent bulletin.

A question will naturally arise in regard to the part played by water and the condition of the plant at the time this may be applied. While I hold this to be the first and most important question in irrigation, I do not know that anyone has actually studied it. I have made some observations in regard to its effect upon the production of yellow-berry. The observations are not wholly consistent in details, but are concordant in showing that neither the time of application nor the total amount applied stands in any casual relation to the development of the yellow-berry. I have samples of "dry land" wheat raised without irrigation in which it is difficult to find a single kernel entirely free from this affection and I have also samples of wheat grown with the application of three acre-feet of water plus some rainfall and this, too, is very badly affected. Some of my own samples were grown with the application of two acre-feet, some with one and one-half acre-feet, and some with one acre-foot, and I can discover no relation whatsoever between the amount of water applied and the prevalence or absence of yellow-berry. I have stated very plainly and the plainness was intentional, that the giving of the percentage of affected berries does not adequately express the differences between samples grown with the application of nitrates and those grown with the application of potassium. The appearance of the kernels is different, the one is translucent and the other is opaque. This holds too in the case of irrigation, i. e., while the yellow-berry may be very bad heavy irrigation seems to slightly improve the appearance of the berries. I have two sets of three samples each which received one, two and three acre-feet of water respectively, and those samples receiving the three feet of water are the better appearing samples, while they are practically all affected with yellow-berry, I feel perfectly justified in stating that the application of irrigating water up to three acre-feet, does not produce the yellow-berry and also that the withholding of all water will not prevent it; for the yellow-berry is independent of this factor.

The remedy is plain, increase the ratio of nitrogen to that of potassium in the soil. This does not mean that it is necessary to

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add nitrogen because there is a deficiency of it to grow a crop. Our check plots grew good crops, from 31 to 43 bushels per acre, but the wheat from the check plots was badly affected with yellow-berry, while the wheat from our nitrogen plots was all practically free from it.

I have my doubts whether it will ever be feasible for our farmers, and probably it will not be feasible for many farmers anywhere to use sodic nitrate to prevent the formation of yellow-berry. There are other considerations to be weighed besides the cost, but this alone is probably prohibitive. This, however, will depend upon the amount which may be found necessary to apply.

The minimum amount necessary to apply will be found to vary greatly depending upon the soil and the time of application.

The observation of Moertlbauer that an early application of nitrates to winter wheat increased the mealy or yellow-berries does not apply, according to our observations, to spring wheat for we have had very favorable results in suppressing the yellow-berry by making but one application at the time of sowing the seed. I do not know but that better results would have been attained, in fact, I think that we would have attained much better results, had this same application been made after the grain had set, but this would have required us to apply water enough to carry the nitrate into the soil. Our plots received two applications of nitrate. There are other phases to the question which would take us too far afield to attempt to discuss in this place, but it may be stated, that it is an easy matter to add too much nitrate. I am not prepared at this time to suggest the minimum quantity likely to be effective, the best time to apply it, or the maximum which may be used without disadvantageous results. The quantity to be added will vary with the soil, and it may be that but few farmers could wisely follow any definite rule with the same results.

A point which demands mention in this place is, that as soon as the ratio of the nitrogen is too high, we obtain shrunken wheat irrespective of other conditions, and also abnormal ripening. The top and bottom portions of the straw will turn yellow while the middle portion and the leaves are too green to cut without danger of the sheaves rotting. This is a condition which I understand is frequently complained of by our farmers. The appearance of shrunken kernels without any apparent, adequate cause has also been noted very often.

Wheat seems to be very sensitive to these conditions, though almost all of our writers on this subject have attributed only a minor importance to them, claiming that climatic conditions almost wholly determine the character of the grain. While we cannot

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make ourselves independent of climatic conditions, however much or little we may mean by the term, it is evident that our data given do not fit into this view. I have omitted any detailed discussion of the composition of the yellow-berry wheat on purpose to avoid a premature discussion of these points. It seems wise, however, to make the above statements lest some one should be led to expect too much from the adoption of our suggestions for the prevention of yellow-berry.

Wheat affected with yellow-berry is considered inferior in quality and is graded low on the market. The removal of this affection will certainly cause the wheat to be graded higher and probably also actually improve the quality, but this seems to be an open question, for the Hungarian wheat is of the best quality though, as we have seen, the wheat is very far from being free from this affection.

There is another way of combating the trouble, the one suggested by Dr. Kosutany, i. e., through thorough cultivation and manuring, also by a proper rotation of crops. In offering an explanation for the smallness of the kernels and the inferior quality of wheat grown on small farms, as compared with wheat grown on large estates in Hungary, he uses the following language:

"The balance swings in favor of the large landowner and intensive, thorough culture, according to the determination of the degree of mealiness which at first sight is rather surprising, for if the wheat grown by the small landowner is smaller-grained, then it should, according to the theory which we have proposed, not only be richer in protein but also flintier, because the wheat planted with shallower culture ends its assimilative activity earlier and should contain less starch and more gluten and, therefore, should be characterized by a higher degree of flintiness. That this is not so can be explained only by this, that the fields on smaller estates were not sufficiently manured and the wheat plants were not supplied with a sufficiency of nitrogen by these soils to form therefrom the protein corresponding to the (other) conditions. Furthermore, it is possible, that a less advantageous rotation plays a part in it, in that the smaller owner has planted his wheat after a plant (crop) that has exhausted the available nitrogen of the soil so that the wheat grown after it, even with an ordinary manuring must be low in its nitrogen content. Accordingly we can draw the conclusion that the wheat grown upon small farms, is of lower value, because it has a lower weight per hectolitre, is smaller grained and less flinty, contains less gluten and less protein. Here a wide province opens up to intensive, thorough cultivation, since with the deepening of the soil the vegetative period of the wheat is lengthened, the kernels do not shrink, the plant is more richly supplied with nitrogen, its roots penetrate deeper into the soil and can take up a richer supply of nourishment. The heavier manuring provides the wheat with richer nitrogenous food and contributes to the formation of a wheat richer

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in gluten, flintier, with great absolute weight and a higher weight per hectolitre."

The effect of crop rotation is well illustrated by a case observed by Prof. Keyser while he was connected with the U. S. Department of Agriculture and stationed in Nebraska. Prof. Keyser has fully stated this case in a letter addressed to me on the subject and with his permission I state it in his own words:

"A certain field in York county, Nebraska, had grown corn for a number of years. A portion of the field had been seeded down to clover. The year the clover was broken up the corn land was seeded to oats. The clover and oat stubble were broken up and the entire field seeded to Turkey Red winter wheat. The year was favorable to good production and a good yield was returned on both parts of the field. The wheat from the land which had been in corn a number of years, however, contained a very high percentage of yellow-berry, although it was otherwise of good quality. The wheat on the clover sod, however, had very little yellow-berry, although there was an occasional kernel in evidence. Aside from this difference there was very little difference to be detected in the wheat from both parts of the field.

"The owner sent the wheat to the Nebraska State Fair, sending samples from each portion of the field. There was no appreciable inferiority of the yellow-berry wheat except the presence of the yellow-berry, both samples being unusually good. As I remember it, this wheat was seeded in the fall of 1902, harvested in 1903 and exhibited that fall."

It is altogether in keeping with what we believe about the effects of various crops to assume that the corn and oats had exhausted the available nitrogen in that portion of the field which had been planted successively to these crops, while the clover had actually added nitrogen to the soil increasing the ratio of the nitrogen supply to that of the potassium with the results above given. Prof. Keyser states that the yield was a good one and that the samples of wheat exhibited were unusually good, therefore, we are free to infer that the land had not been exhausted so far as crop production was concerned nor was the wheat affected with any other trouble than yellow-berry.

There is still another way to reduce or prevent the trouble, it is to cultivate the land fallow for one season during which some of our lands will acquire nitrates enough to produce a crop of wheat but little affected with yellow-berry. The department of agronomy under Prof. Keyser is conducting experiments with wheat on land sixteen feet to the west of that on which I am conducting my experiments. I am cropping continuously and he is cropping and cultivating fallow alternate years. The grain on my check plots comparable to his land produced wheat in 1914 having 97 and 98 percent yellow-berry, his wheat showed 14 percent yellow-berry.

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The wheats received essentially the same treatment throughout the season, irrigation and care, except that his was harvested by hand and mine with a reaper. This comparison is of Red Fife with Marquis. In comparing Kubanka grown from my own seed on fallowed ground and grown on my check plot, I find that grown on fallowed ground to contain 13 per cent of affected berries and that grown on my cropped ground is practically all affected, by actual count 97 percent. It may be argued that my land was deficient in nitrogen because I had grown a crop of wheat on it the preceding year and had added no nitrogen to compensate for what I had taken off; this is true, but I had not affected the producing capacity of the soil, as the crop harvested was 43 bushels of wheat weighing 65 pounds per bushel. On the other hand we know that this land rapidly enriches itself in nitric nitrogen, so much so, that in October 1914, fallowed land, now planted to wheat contained nitric nitrogen equivalent to 518 pounds of sodic nitrate taken to a depth of seven inches. Such land will not produce yellow-berry.

It is evident that different pieces of land will require different treatment and no rule can take the place of intelligent observation and some experimentation on the part of the grower himself. The difference in composition and quality of flinty and yellow-berry kernels have been reserved for later discussion.

SUMMARY.

The appearance of yellow or white, mealy or half-mealy, or spotted kernels in wheat, otherwise without apparent blemish and known as Yellow-berry, is not due to over-ripeness, nor to exposure after cutting, nor to the action of fungi, nor is it a "tendency" heritable in the wheat, as has been claimed by different authors.

We have no substantiation of the claim sometimes made that climatic conditions favorably influence, the development of, or cause yellow-berry.

Yellow-berry can be very much lessened or entirely prevented by the application of a sufficient quantity of available nitrogen.

Yellow-berry can be greatly intensified or increased by the application of available potassium.

The application of available phosphorus has no appreciable effect upon its prevalence.

Yellow-berry is not indicative of an exhausted soil, that is, one which will not produce abundant yields.

Yellow-berry indicates that potassium is present in excess of what is necessary to form a ratio to the available nitrogen present, advantageous to the formation of a hard, flinty kernel.

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Yellow-berry should not be mistaken for or confused with black-ended berries or with brown or other discolorations in the berries. These affections are not general affections as the yellow-berry is and are not produced by the same cause.

Yellow-berry is under the control of the grower. If there be sufficient difference in the price of grain produced he can control it with a margin of profit.

The means at his disposal for its control are:

First: The judicious use of sodic nitrate.

Second: The thorough cultivation of his soil with the application of nitrogenous manures.

Third: A rotation of crops in which a clover and possibly other legumes precede the wheat.

Fourth: Fallow cultivation.

These observations apply to all of our western soils, rich in potassium and relatively, not absolutely, poor in available nitrogen.

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The Agricultural Experiment Station

OF THE

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SPUR BLIGHT OF THE RED RASPBERRY CAUSED BY SPHAERELLA RUBINA

By WALTER G. SACKETT

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SPUR BLIGHT OF THE RED RASPBERRY CAUSED BY SPHAERELLA RUBINA

By Walter G. Sackett.

For more than twenty years, the growing of red raspberries in northern Colorado has been one of the chief occupations of those engaged in horticultural pursuits. There is probably no one district in the United States which produces more red raspberries for a given territory than Loveland, Colorado.

In the year 1914, the Loveland Fruit Growers' Association handled 10,120 crates,* which represents approximately 80 per cent. of the crop; the Boulder Association shipped 1,550 crates, less than one-half of the crop, and the Longmont Association 5,000, making a total of 16,670 crates handled in a wholesale way, to say nothing of those marketed through other channels and consumed locally. The average price paid to the Loveland growers for the season 1914 amounted to $1.27 per crate, and estimating the cost of production and packing at 75 cents per crate, we have a net return of approximately 50 cents on every crate. The demand for these berries is always far in excess of the supply, which makes it possible to control the price and secure a reasonable return for the grower. The present acreage in the Loveland district is in the neighborhood of seventy acres; Longmont follows with forty, and Boulder with thirty. In addition to this, there are a number of plantations around Fort Collins which a little more than supply the local trade. Nowhere in the state do we obtain the yields that are secured in the Loveland, Longmont and Boulder districts; 375 crates per acre is a fair average, while 600 have been obtained under optimum conditions.

The Marlboro is the most popular variety, although the Cuthbert is grown to some extent. In flavor, quality, size and color, the Northern Colorado berries are second to none in the United States, but because of inadequate facilities for pre-cooling, a prerequisite to refrigeration in transit, the fruit has not found its way to the eastern and Mississippi Valley markets. Our berries ripen from two to three weeks later than those in the lower altitudes, and while this question of a market has never given us any concern thus far, it is very clear that if such an emergency should

*One crate contains twenty-four pint boxes.

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Figure 1.

arise, we would have little difficulty in disposing of the crop to the eastern trade. At present, we are shipping in the open express car as far east as central Kansas and Lincoln and Omaha, Nebraska; north to Billings, Montana, and south to northern Texas and Oklahoma.

From this brief statement of the raspberry industry in Northern Colorado, it will be seen that any factor or factors which materially affect the production of berries may mean much to the prosperity of the section. An examination of the yields for the years 1910-1913, inclusive, as shown by the shipments made by one of the largest Fruit Growers' Asosciations, indicates clearly that certain agents were operating to bring about a marked decrease in production for that period. In 1909, the association mentioned handled 13,150 crates, while in 1910, only 1,655. Quite naturally, those engaged in the berry business felt considerably alarmed over this state of affairs, and at the request of the most extensive growers, we have undertaken to study the prevalent conditions and to ascertain some of the causes which are contributing to these failures.

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Figure 2.

As a result of six years of observation, we believe that no one factor alone is responsible for this state of affairs, but rather that it has come about through the combination of several, among which we may mention the following: Late frosts, method of covering and time of taking up canes, poor cultivation, age of plantations, and injury caused by *Sphaerella rubina.*

LATE FROSTS.

One of the most disastrous things that can befall a raspberry plantation is to have a killing frost late in the spring after the new canes have begun their growth, and are from 12 to 15 inches high. Frequently, we have a warm, sunny April with moisture conditions just right to produce a rapid, vigorous development of the young canes, and then the first or second week in May we will have a freeze that may damage the new canes very considerably. This is exactly what happened in the springs of 1909 and 1910. In the latter year, the spring promised to be an early one; the berry bushes had been uncovered and taken up, and many of the young canes were 12 to 15 inches high. About the middle of May there

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Figure 3.

occurred a severe freeze, and practically every new cane was seriously injured, if not killed outright. The growing tips were blackened and the canes were shriveled for a distance of one-half to three inches below this. When they were split lengthwise, the pith was found to be blackened at the tip, browned further down to within two or three inches of the ground, below which it was white and normal to all appearances.

As soon as favorable weather conditions return, one of two things usually happens: The frozen canes either make no further growth and the roots send up a new crop of suckers, or they sprout out from below the frozen tips and develop a forked cane consisting of two or more spindling shoots in place of one good, substantial cane. Such branched canes are usually undesirable, and if single ones can be obtained, even though of a later origin, their growth should be encouraged. Large, thrifty canes mean handsome returns in berries, while the inferior ones yield nothing but disappointment.

Many growers make the serious mistake of allowing too many canes to develop in the spring. Dr. Sandsten, our horticulturist, recommends that, "each plant or hill should not be allowed to grow

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Figure 4.

more than twelve new canes each year. These should be reduced to eight or ten in the spring. The extra canes are to replace those that happen to break in covering and uncovering. All others should be removed as soon as they appear. By keeping these young canes or suckers down, the strength is thrown into the main canes, thus promoting strong growth and greater fruiting capacity."

METHOD OF COVERING CANES.

Because of the frequent cold winds during the winter months which have a decided drying action on the canes, to say nothing of their freezing effect, it has been found necessary to protect them in some manner.

Different materials have been employed for this, such as straw, strawy manure, and gunny sacks, but nothing has been found quite so satisfactory as soil. Some four years ago, the writer tried a combination of straw and soil, using just enough of the latter to hold the straw in place, the object in this being to keep the soil away from the canes so that in case the following spring should be wet and there should be some delay in taking up the berries, the injury from ground scald and rot would be reduced. It happened,

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Figure 5.

however, that the spring was very favorable to getting the canes up early, so we were not privileged to see the benefit, if any, from the use of the straw. The experiment was not without its lesson, however, for it demonstrated very clearly that straw, even though covered with soil, is not an adequate protection. Although not all of the canes were killed, a very large proportion never came out into leaf.

As checks on this method of covering, part of the same row was left entirely uncovered, and an adjacent row was covered with soil. Every cane that was left unprotected was killed, while every one that was covered with soil grew. The results of these experiments are shown in Figs. 1 and 2.

The right-hand row of Fig. 1 was left uncovered and all the canes were dead. The left-hand row was covered with soil, and

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abundant leaves are to be seen coming out; in Fig 2, the row on the right was covered with straw and soil, that on the left with soil; the former shows numerous bare, dead canes, and a few live ones with scattering leaves, the latter, vigorous canes with many leaves.

That the air had a much freer access to the canes which were covered with straw is evident from two facts: First, a large proportion of the canes were killed, and second, the young shoots or suckers were six to eight inches high, while those that were covered with soil were just coming through the ground, a fact which would seem to indicate that the former had gotten an early start, due to a freer circulation of warm air. The former were more numerous and more stalky than the latter; the same was true of the new growth from the bushes which were left entirely uncovered, but to a less extent.

Fig. 3 shows the vigorous young shoots coming from the straw covered bushes, and Fig. 4 those arising from the roots of the soil-covered canes. The old canes in Fig. 3, straw-covered, but naked and dead, stand out in sharp contrast to the leafy, thrifty ones in Fig. 4 which were covered with soil. The experience of the most successful growers, together with the results of our experiments, point clearly to soil alone as the most satisfactory method of protection during the winter months. A light covering, just enough to exclude the air, possibly two inches over the root ends, is adequate.

TIME TO TAKE UP CANES.

Just when to take the berries up in the spring is always a problem, not because we do not know what practice is best to follow, but because we do not know what weather conditions to expect. On the one hand, if the spring is going to be late, cold and dry, little harm will result if the canes are left buried until after the first of May; on the other hand, if it is warm and wet, nothing could be more disastrous than to allow them to remain covered until this late date. The danger from uncovering and taking them up too early results from subsequent late freezes during the first part of May. The fruit spurs are usually well advanced by this time, and the new canes are six to eight inches in height. If the bushes are left covered until late and the weather is warm, with considerable moisture, the canes throw out long, spindling white shoots which wilt and shrivel as soon as they come into contact with the air and sunshine, particularly if there is a little wind blowing: this, of course, means that the canes must grow a second set of fruit spores, which, at their best, are inferior to the first. While there is some difference

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Figure 6.

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of opinion concerning the wisdom of early or late uncovering, the most successful growers are agreed that the former procedure is the safer practice.

The method adopted consists in plowing away the soil from the sides of the row early in April, and in gradually removing the soil from the top so as to admit air and sunshine. In this way, the young growth becomes accustomed to the new conditions gradually, and is hardened off before it is completely exposed; at the same time, the canes have an opportunity to dry off, and if severe cold weather does follow, they will be in a more resistant condition than if saturated with water. The canes may be left in this semi-covered condition for eight to ten days, or even longer, if cold weather prevails, without doing them any injury. With this preliminary hardening, they should be ready to take up by the middle of April, and should be able to withstand rather wide ranges of temperature.

POOR CULTIVATION.

Another factor which has undoubtedly played a part in the reduced yield of many plantations is insufficient and improper cultivation. We have depended too much upon irrigation, and not enough upon cultivation to maintain the proper moisture content of the soil. The result has been that the soil in the raspberry row has become puddled, hard, and so tightly compacted that it is practically impossible for the irrigating water to penetrate and reach the roots. Without sufficient moisture, the plants are unable to obtain the necessary mineral food from the soil, and starvation is the result. Furthermore, the roots must have air for the growth and development of the bushes, and with the soil packed so firmly around them, proper aeration of the root system is impossible.

In place of planting in drills or rows, a hill system would be more desirable since cross-cultivation would then be possible, and it would be a relatively simple matter to break up the hard ridges between the hills. Where planting has been carried out in rows, much good can be accomplished by tearing up the hard soil between the bushes with a grubbing-axe or mattock several times during the season.

AGE OF PLANTATIONS.

Experience has shown that although given the best of care, raspberry bushes begin to deteriorate quite rapidly after the plantation has reached the age of twelve to fifteen years. Even where thorough cultivation and systematic manuring have been practiced faithfully, we find that the old roots lack the vitality necessary to

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produce vigorous fruiting canes. There is no question but that some of the plantations in Northern Colorado are suffering from old age and should be plowed up and consigned to the brush pile. This factor alone, in many cases, will account for decreased yields.

In place of re-setting the land to berries at once, it would be much better to plant it to some hoed crop for a year or two, in order to get the old raspberry rows thoroughly broken up. At the end of this period, the land may be seeded to alfalfa or sweet clover, in which case the alfalfa should be plowed under in the fall of the second or third year, and the sweet clover at the end of the second year. In place of cutting the last crop for hay, this should be turned under and used as a green manure, in which capacity it will yield a much greater return than if harvested for hay. This done, the land may be again set to raspberries.

INJURY CAUSED BY *SPHAERELLA RUBINA*.

Description of the Disease.

The first indications of the injury here referred to make their appearance about the middle of July. If the young, green canes are examined carefully, chocolate brown discolorations of the epidermis will be found occurring on the lower portion of the cane in the region of the point of attachment of the leaves, the node; again, small spots may occur between the nodes, the internode, and on the petioles of the leaves. The petiole infection is shown at 1, and the node infection at 2 in the colored plate which was prepared from material collected August 9, 1913. The whole area surrounding the growing buds at the base of the leaves soon becomes involved and turns brown; the buds appear to stop their development, shrivel and drp up. If the developing bud is not killed outright during the fall and winter, it is so weakened that the following spring it is able to send forth only a small, weakly spur which may come into leaf, but rarely reaches the blossom stage. The leaves on such spurs are usually small, yellow, and apparently poorly nourished. They struggle along for a few weeks, and usually die of starvation. The result of this condition is a cane with practically no fruit-spurs for a distance of 20 to 24 inches above the ground, and with only the upper half producing berries. (See Fig. 10.) There certainly is little ground for argument that a patch in this condition is producing all that it might and is a paying investment.

In the case of the petiole infection, the nourishment seems to be interfered with so seriously that the stem soon collapses and the whole leaf droops and ultimately dies, leaving nothing but the dry stem remaining. (See Fig. 3 colored plate.)

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Figure 7.

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The infection at the node can be traced, in nearly every case, to a lesion on the petiole which has spread toward its base and involved the bud region. From the nodes, the discoloration spreads rather rapidly into the inter-nodes, the discoloration from one coalescing with that from another, sometimes entirely encircling the cane, so that in six weeks time the whole bottom third may be dark, purplish brown in color. Fig. 5 shows a portion of two such canes on the left, and a healthy one on the right. In Fig. 6, four diseased (left) and three normal (right) canes are given to illustrate the distribution and extent of the discolored areas late in the season. (Sept. 13, 1913.)

The bark or cortex frequently cracks and splits for a distance longitudinally, where it has become brown and exposes the moist, green tissue beneath. (Fig. 4 colored plate.) As a result of this, the canes dry out prematurely, become brittle and break very easily, when they are put down in the fall and taken up in the spring. This fact coincides with the statement of the growers that the canes have become more brittle in recent years than formerly. Whereas less than 5 per cent. should be lost in this way, some growers estimate the number as large as 30 to 50 per cent.; some report only 2 per cent. broken, while the average is between 10 and 20 per cent.

From the middle of September to the first of October, grayish white patches may be seen developing in the center of the brown blotches (Fig. 7), and if these light areas are examined very carefully a few weeks later, they will be found to be thickly studded with minute black specks or pustules. (Fig. 8.)

Pathological Changes.

A microscopic examination of a cross-section of a raspberry cane discloses three rather well defined cortical regions beneath the epidermal layer. The outer one consists of relatively large thick-walled cells along the outer edge, the middle one of large thin-walled cells, and the inside one of smaller thick-walled cells. By exercising special care, it is possible to separate the outside structure from the inside with a sharp scalpel, owing to the fragile character of the large thin-walled cells of the middle region. If the outside portion is removed from a healthy, green cane free from all discoloration, the aspect of the remaining inside region is almost white with a faint suggestion of green. If a similar dissection is made of a brown diseased cane thru the brown spot, both the outside and inside portions of the cortex will be found to be brown in color. Such a dissection is shown in Fig. 9. Here the outside part was peeled from adjoining normal and diseases areas and

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shows the change in the color of the deep layers, in passing from healthy to diseased tissue. From A to C the cane was normal and green in color; the outside cortex was removed from B to D; from B to C the inside cortex was white; from C to D it was brown; from D to E the cane was brown. This discoloration appears to the naked eye to extend no deeper than the cortex, but a microscopic examination of a section shows that this is not altogether correct.

Figure 8.

The cells of the entire cortical layer, from the epidermis to the phloem, are badly shrunken and present a brown shriveled aspect characteristic of dead, collapsed tissue. Many of the phloem elements, as well as the cells of the medullary rays show an accumulation of food material greater than that of corresponding cells of normal tissue. While these cells appear amber brown in color, they are perfect in outline and in general structure, and do not suggest a fungous invasion. The brown color which they exhibit is traceable, in all probability, to the excessive food material which has been deflected to these regions as a result of the enzymotic influence, exerted by the fungus which has invaded and destroyed the adjoining cortical layer. The strengthening tissue (stereome), wood (xylem), and pith (medulla) exhibit no pathalogical condition.

The Causal Organism.

A microscopic examination of the brown cortical tissue shows it to be permeated with the mycelium of a fungus. This fungus has been isolated repeatedly with little difficulty from such material and has been grown for more than three years upon standard

Figure 9.

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nutrient agar, plus 15. It has been re-inoculated into healthy canes from pure cultures by means of needle punctures, and typical brown splotches characteristic of the injury have been produced inside of two weeks; from the lesions thus produced, the original fungus has been re-isolated. Both the brown septate mycelium and the fruiting bodies (perithecia) present on the canes, as well as the changes produced in the plant, correspond to the description of the pyrenomycete, *Sphaerella rubina,* and its attendant injuries given by Peck in the 48th Annual Report of the New York State Museum, Part I, page 114. The description follows:

"*Sphaerella rubina* n. sp. Perithecia minute, .007 to .009 in. broad, commonly gregarious, sometimes forming extended patches, submembraneous, obscurely papillate, pertuse, subglobose or depressed, at first covered by the epidermis, becoming superficial when the epidermis falls away, black; asci cylindrical, subsessile, .003 to .0035 in. long, .00045 to .0005 broad; spores uniseriate or subbiseriate, oblong, obtuse, uniseptate, generally constricted in the middle, hyaline, .0006 in. long, .00024 to .0003 broad; the upper cell often a little larger than the lower.

"Stems of cultivated raspberries. Menands. April and May.

"This species is injurious to the plants it attacks. The affected plants either die from the disease or are so weakened by it that they are winter-killed wholly or in part. Generally the epidermis is whitened over the patches of the fungus, but some times brown spots indicate the presence and location of the fungus. The mycelium consists of brown septate filaments. From *Didymella applanata,* which this fungus resembles in some respects, it is separated by the absence of paraphyses."

Stewart and Eustace*, while investigating the cause of raspberry cane blight, which they believe to be due to a species of Coniothyrium (C. fuckelii?) have found *Sphaerella rubina* associated with Coniothyrium. However, they are of the opinion that this organism is not injurious to the canes on which it occurs, and plays no part as a casual agent in cane blight in which the wood itself is attacked. Our trouble is manifestly distinct from cane blight, for in no case is the wood involved.

Concerning the injury to red raspberries by *Sphaerella rubina* in New York State, Peck** gives the following:

"Having been informed that the raspberry patches of the fruit growers in the vicinity of Marlboro, Ulster County, were suffering from disease, and wishing to know the cause of it, a visit

*Bulletin 226, N. Y. Exp. Station, Geneva, N. Y., p. 357, Dec., 1902.

**Sixty-fourth Annual Report (1910) N. Y. State Museum—State Botanist, p. 7, 1911.

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Figure 10. Unsprayed Canes.

was made to that place in July. An examination of the diseased canes showed that they were suffering from an attack of a parasitic fungus, whose technical name is *Sphaerella rubina* P. The fruiting canes develop their leaves and flowers as usual, but before the fruit ripens it withers and dies in the branches. The dryness of the season and an attack of 'red spider' were apparently contributing causes of the failure of the crop, and the loss was severe. The diseased canes bear patches of the fungus. It matures its spores early in the season. In the type specimens, they were found in May. The young canes showed brown or blackish patches one or two inches on the lower part. In some cases they were near the ground, thereby indicating a probable infection when they were but a few inches tall. These spots had not yet developed their

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Figure 11.

perithecia or spore cases, but doubtless would toward the end of the season and the next spring be ready to shed their spores and renew the species in the succeeding crop of young canes. Theoretically, the disease should be prevented by spraying the young canes with a good fungicide like Bordeaux mixture or lime-sulphur mixture, but it would be necessary to give the first spraying when the young shoots are only three or four inches high. This should be repeated once a week until the canes of the previous year begin to blossom."

As mentioned above, during the latter part of September or the first of October, there appear on the gray discolorations of the brown splotches numerous tiny black pustules under the epidermis of the new canes. These resemble little pimples pushing up under the skin and are the developing perithecia or spore cases of the fungus (See Fig. 8.) They mature early in the spring, producing a large number of spores or seed which are destined to spread the disease. The pustules break through the epidermis, burst and liberate millions of spores to be carried by the wind to new tender canes just coming through the ground, or at best but a few inches

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Figure 12. Sprayed Canes.

high. Once located on the new succulent growth, the spores germinate, begin active invasion of the cortex, and in due time the characteristic brown splotches appear.

It is clear from this description of the time and method of infection that if any remedial measures are to be resorted to, such measures must be directed toward protecting the young developing canes against the attack of the fungous spores, as early in the spring as possible. This is best accomplished by covering them with some poison or fungicide before the spores begin to scatter, which will not permit their growth and development when they alight.

Too much stress cannot be laid upon the importance of the early application of the fungicide or spray material, since it is of no value whatever after the fungus has once invaded the deeper tissues. Prevention is our only hope of combatting the trouble,

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for we have no remedy, save a plow, when it has become once established. Spraying will prevent the disease.

Control Measures.

For the past two years we have been carrying on spraying experiments at Loveland, Colorado, in an effort to control the Sphaerella injury. In this work we have used an adhesive bordeaux mixture composed of 3 pounds of copper sulphate (bluestone), 2 pounds of stone lime, and 50 gallons of water (3-2-50), to which 2 pounds of rosin fish oil soap were added as a sticker.

Figure 13. Sprayed Cane.

In 1913, the first application was made May 29th, at which time the new canes were from 8 to 12 inches high; the second spraying was made on June 12th, and it was our purpose to give a third application about June 26th, making the three treatments approximately two weeks apart, but because of continued rainy weather, it was impossible to get into the patch with a spraying outfit, so this had to be abandoned. The berries were beginning to ripen by the time the ground had dried off, and nothing more was done until the picking season was over and the old canes were all removed. On August 18th, a final application was given, to carry the bushes into fall and winter in a protected condition. At this time, scattered here and there through the patch were a few canes with one or two brown splotches, but nowhere nearly as numerous as in unsprayed plantations. In 1914, sprayings were made as follows, on the same patch: June 4, June 22, and August 18th. This time, the late June spraying was prevented by the very early ripening of the berries, it being deemed

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inadvisable to use the Bordeaux mixture, because of the danger of discoloring the fruit.

It is understood, of course, that the Bordeaux mixture is applied to the young canes only, and not to the fruiting canes, since it is the former that we wish to protect from possible infection from the old diseased canes. In spraying raspberries, as well as other things, it must be remembered that thoroughness is what counts; great care should be exercised to see that every part of the cane. particularly the portion next to the ground, is entirely covered with the spray material each time the operation is carried on. In place of attempting to spray both sides of the row and between the bushes at the same time, requiring the operator to reach around them, we have found it more practical and more expeditious to drive between the rows, to treat the inside of the rows next to us and part way between the bushes, and then to drive down the next middle and finish the other side of the former row and one side of a new row.

The old fruiting canes should be removed and burned as soon as the berries have been gathered in order to prevent any possible infection of the new canes.

Preparation of Bordeaux Mixture.

We have found a barrel spraying outfit adequate for this work and entirely satisfactory. The pump employed should be capable of giving at least 50 pounds pressure, and can be purchased for from ten to twelve dollars, exclusive of the barrel.

For preparing the Bordeaux mixture, it will be found convenient to have two half barrels with a capacity of about 30 gallons each, made by sawing in two a 60 gallon barrel. Three or four wooden candy pails should also be provided.

For every 50 gallons of Bordeaux mixture, dissolve 3 pounds of copper sulphate in two or three gallons of boiling water in one of the wooden pails, and slake the corresponding amount of lime. 2 pounds, in another, using just enought water to keep the lime from burning, and to give a thick, smooth paste, of about the consistency of white-coat. Two pounds of rosin fish oil soap are dissolved in about 2 gallons of water. The solution of copper sulphate is next poured into one of the half barrels, and enough water added to make 25 gallons; the slaked lime is washed into the other half barrel, with enough water added to make 23 gallons; the 2 gallons of water on the soap will make the 50 gallons of water shown in the formula 3-2-50. The diluted solution of copper sulphate and lime are now ready to be mixed. No better method has been devised for doing this on a small scale than that shown in

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Figure 14. Sprayed Canes.

Fig. 11. The two operators, each provided with a bucket, dip up equal amounts of the copper sulphate and lime solutions, respectively, and pour them together at the same rate at a height of two or three feet above a mixing-barrel. (See Fig. 11.) This permits of thorough mixing in falling, and in view of the fact that the value of Bordeaux mixture as a fungicide depends largely upon its method of preparation, the procedure here described should be adhered to rather closely. After the lime and bluestone have been brought together in the mixing barrel, the whole should be stirred thoroughly with a long paddle, at which time the soap solution may be added. It is now ready for use.

Cost of Materials.

The commercial copper sulphate can be obtained in 100 pound

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Figure 15. Unsprayed Canes.

quantities from the Mine & Smelter Supply Company, Denver, Colorado, at 7 cents per pound, f. o. b. Denver. Stone lime can be purchased locally for $1.75 per barrel of 200 pounds. Rosin fish oil soap can be obtained from James Good, Number 939 North Front Street, Philadelphia, Pa., at the following prices, f. o. b. Philadelphia:

25 lb. buckets at 5c per lb.
50 lb. buckets at 4½c per lb.
100 lb. buckets at 4¼c per lb.
170 lb. buckets at 4c per lb.
Half barrel (275 lb.) at 3¾c per lb.
Barrel (about 425 lb.) at 3½c per lb.

At the above prices, 50 gallons of Bordeaux mixture cost approximately thirty-two cents, and 400 gallons, the quantity re-

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quired for one acre, would amount to $2.56. If four treatments are given during the season, three before picking at intervals of two weeks, and one immediately afterwards, the cost per acre for the season would be $10.24, an amount offset by eight or ten crates of berries; if the yield cannot be increased more than ten crates per acre by spraying, one would certainly be justified in the position that "the game is not worth the candle."

By giving three applications of Bordeaux mixture as mentioned above, we have reduced the number of diseased canes and the extent of the infections on these canes to less than seven per cent., and had we been able to carry out four sprayings as was our purpose, we have reason to believe that the injury could have been reduced to practically zero.

Results of Spraying.

A comparison of Figures 12 and 13 with Fig. 10 suggests a very plausible and satisfactory explanation of the increased yield on the part of the sprayed canes. All of the canes shown in these illustrations are cut close to the ground; those in Figs. 12 and 13 threw out strong, vigorous fruit spurs 16 to 18 inches long, all the way to the ground; those in Fig. 10 have practically no spurs within 18 to 24 inches of the ground; the former were sprayed, the latter were not, and it is obvious that the canes with the larger number of spurs will produce more fruit than the naked ones. By an actual count of the fruit spurs on the lower 24 inches of 100 sprayed canes, the average number was found to be 9.82, while on a like number of unsprayed canes, there was but 3.55 to the first 24 inches. Again, 65 per cent. of the sprayed canes had their lowest fruit spur within 6 inches of the ground, 32 per cent. from 6 to 12 inches, and 3 per cent. above 12 inches; with the unsprayed canes 37 per cent. had the first spur within 6 inches of the ground, 41 per cent. from 6 to 12 inches, and 22 per cent. above 12 inches.

In Figs. 14 and 15 are shown sprayed and unsprayed canes, respectively, in the spring condition just as they are leafing out. The sprayed canes with their numerous leaves present an entirely different picture from the naked, spindling ones which were unsprayed.

Below are given the actual returns from an experimental patch which was sprayed three times:

Mr. A. H. Gifford, Loveland, Colo.—1½ acres.

Crop of 1912—Unsprayed canes	200	crates
1913—Unsprayed canes	200	crates
1914—Sprayed canes	735	crates
Increase in yield for 1914 over 1913	535	crates
Gain per cent. for 1914	267.5%	

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Unsprayed Patches.

Mr. A. 1¼ acre—	1912	300 crates
	1913	400 crates
	1914	275 crates
Mr. B. 4 acres—	1912	1,000 crates
	1913	1,135 crates
	1914	1,216 crates
Mr. M. ⅞ acres—	1912	330 crates
	1913	350 crates
	1914	570 crates
Mr. S. 1/3 acres—	1912	100 crates
	1913	125 crates
	1914	115 crates
Mr. A. 1⅛ acre—	1912	93 crates
	1913	273 crates
	1914	310 crates
Mr. K. ½ acre—	1912	175 crates
	1913	240 crates
	1914	324 crates
Mr. S. 1¾ acres—	1912	285 crates
	1913	421 crates
	1914	453 crates
Mr. S. 1/3 acre—	1912	75 crates
	1913	106 crates
	1914	70 crates
Mr. M. 1 acre —	1912	200 crates
	1913	250 crates
	1914	330 crates
Mr. S. 1 acre —	1912	175 crates
	1913	278 crates
	1914	532 crates
Mr. S. ¾ acre —	1913	487 crates
	1914	365 crates
Mr. C. 1¾ acres—	1913	373 crates
	1914	373 crates
Mr. L. 1 acre —	1912	325 crates
	1913	250 crates
	1914	300 crates

The increase in yield for the year 1914 over that for 1913 due to more favorable climatic conditions amounts to 22.1 per cent. This figure represents an average from the returns of 21 unsprayed plantations around Loveland, Longmont, and Boulder.

It has been shown that where the bushes were sprayed, the increase of 1914 over 1913 was 267.5 per cent. Deducting from

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this the per cent. of increase assumed to be due to the favorable season, we still have 245.4 per cent. more berries from the sprayed than from the unsprayed canes, or 91.75 per cent. of the season's increase was the result of spraying. This represents an increase of 375 crates per acre, which, at a net profit of 50 cents per crate, would amount to $178.50, and deducting from this the cost of spray material for one acre, $10.24, for the season, there would remain for the grower a net gain of $167.26 per acre.

Whereas, under the present condition, the Fruit Growers' Associations in northern Colorado in 1914 handled 16,670 crates of red raspberries, there is little reason why this could not be increased to 50,000 crates, if systematic spraying were to be adopted generally.

ACKNOWLEDGMENT.

I am indebted to Mr. W. O. Fletcher, manager of the Loveland Fruit Growers' Association, to Mr. G. V. Booth of the Longmont Association, and to Mr. L. H. Stanton of the Boulder Association, for the data relative to their respective associations.

To Mr. A. H. Gifford of Loveland, I am indebted for the numerous courtesies extended in connection with our spraying experiments which were carried out on his plantation.

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Bulletin 207 May, 1915

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

THE COLORADO STATUTE INCH AND SOME MINER'S INCH MEASURING DEVICES

By V. M. CONE

This bulletin is based upon work done in the hydraulic laboratory, at Fort Collins, Colorado, under a co-operative agreement between the Colorado Experiment Station and the Office of Experiment Stations, U. S. Department of Agriculture

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THE COLORADO STATUTE INCH AND SOME MINER'S INCH MEASURING DEVICES

By V. M. CONE

The question is often asked, "What is a Miner's Inch," or an "inch of water?"

The "Inch" is a unit of measure of flowing water which has been handed down to the irrigators of the West by the early day miners. There are several different Miner's Inches, and they are sometimes called "Customary Inches," which means the "Inch" principally used in any certain locality. When the value of the "Inch" or the conditions under which the "Inch" shall be measured is fixed by law, it is called a "Statute Inch."

An "Inch" of water is an indefinite quantity. It is the flow through an inch square orifice, but the flow varies with the size of the orifice, the distance from the top of the orifice to the surface of the water, and the method of placing the orifice. These conditions are not uniform in the different localities and it is not uncommon to see different standards on a single irrigation ditch. The depth of the orifice varies from 1 to 12 inches and the water pressure varies from zero to 6 inches above the top of the orifice. The orifice may be thin edged or a square cut leaving the edge the full thickness of the plank, and the issuing stream of water may flow free into the air or it may be partly covered by "back-water" on the down-stream side. The orifice may be placed in a large box where the water is practically at rest, or it may be placed in a small box where the water approaches the orifice with considerable velocity. Sometimes the orifice is the open end of a long box or tube placed in a nearly horizontal position through the ditch bank. Each of these conditions affect the quantity of water which will flow through a square inch of the orifice and it will therefore be seen that the "Inch" of water may be a variable quantity when measured in accordance with the following Colorado law:

"———; and water sold by the inch by an individual or corporation shall be measured as follows, to-wit: Every inch shall be considered as equal to an inch square orifice under a five-inch pressure and a five-inch pressure shall be from the top of the orifice of the box put into the banks of the ditch, to the surface of the water; said boxes, or any slot or aperture through which such water may be measured, shall in all cases be six inches perpendicular, inside measurement, except boxes delivering less than twelve inches, which may be square, with or without slides; all slides for the same shall move horizontally and not otherwise; and said box put into the banks of the ditch shall have a descending grade from the water in ditch of not less than one-eighth of an inch to the foot." (L. '74, p. 308.)

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According to ex-State Engineer, John E. Field, the above law, which was passed in 1874, was drafted to meet the conditions under which irrigation water was being measured at that time in the vicinity of Denver. A box made of boards 16 feet long was placed through the ditch bank, and it was given a grade of at least one-eighth of an inch to the foot. If the irrigator had a water-right of 36 inches, the box would be made 6 inches square, inside measurement, and for 60 inches, it would be made 6 inches deep by 10 inches wide. It is interesting to note that although the law was intended to apply to the flow through such tube-boxes, it is so worded that it applies to practically all types of inch devices. Very few tube-boxes are used in Colorado now, nearly all inch measurements being made through thin edged orifices placed in the vertical side of a box so the issuing stream of water flows free into the air.

Former State Engineer, Nettleton, computed the flow through an orifice to correspond to the Colorado law, and stated the quantity to be 1/38.4 of a cubic foot per second. This value has been assumed to be the value of the Colorado "Statute Inch."

In order to secure definite information concerning the Colorado statute inch a series of experiments were made in the hydraulic laboratory, at Fort Collins, Colorado, during the fall of 1914 and the spring of 1915. The results of these experiments are given in the tables in this bulletin for the use of engineers and others who may have need of the actual data. Experiments were also made with one type of measuring device used in the Uncompahgre Valley, and with one of the Miner's Inch devices used in Southern California known as the Azusa hydrant.

COLORADO STATUTE INCH.

Box-Tubes.—Many of the water rights in Colorado are stated in inches, though there are but few irrigation systems in the state under which the water is actually measured in inches. The water is usually measured in second feet, but it is necessary to know the quantity of water that will flow through orifices under the terms of the Colorado law in order that the irrigator may receive the amount he is entitled to.

In reply to an inquiry concerning the method of installing the outlet or tube-box, Mr. John E. Field gave the following description of the practice of 30 or 40 years ago. "In the earlier practice it was seldom that an effort was made to regulate the head over the outlet boxes. Where this effort was made, it was by means of a box or long-crested weir which would discharge back into the ditch the surplus water entering the box. This box or flume was placed parallel to the bank of the ditch and the outlet box was placed at the lower end. This did not regulate the head absolutely, but only approximately. Where this method was not used, the boxes were placed so that when the ditch was at normal stage there would be a 5-inch pressure. When there was a greater amount of water in the ditch, then the discharge through the box was greater, and when it was less it was in the nature of cutting down the amount purchased and a rough pro-rating of the available amount. When the ditch was very low this pro-rating was done by shutting down the boxes partially,

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even below the amount which had been purchased. Sometimes the head was maintained by having a check in the ditch, but when the amount of water in the ditch was small, this was generally prohibited, as those at the upper end of the ditch would receive their full amount and those at the lower end would get practically nothing."

The results of the experiments with tube-boxes are given in table 1. The boxes were 16 feet long and were given a descending grade of ⅛-inch to the foot. The discharge end was therefore 2 inches lower than the intake end. Metal strips ⅛ inch thick were placed around the intake end of each box so the inside dimensions of the orifice could be accurately determined. The inside depth of the box was practically 6 inches in every case and the water surface was 5 inches above the top of the orifice. So far as the law is concerned, the width of the box need not be the same as the width of the orifice, and experiments were therefore made with different widths of boxes for each width of orifice. A thin metal slide was made to fit between the metal strips on the end of the box, and this was adjusted to give any width of opening from 2 to 16 inches.

TABLE 1.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES (TUBE BOX).

	Orifice				Discharge in Cubic Feet per Sec.			
No. of Experiment	D Depth in Inches	B Breadth in Inches	Nominal Area in Sq. Inches	Width of Box Inches	Observed By Experiment	Corrected for Nominal Area	Curve Value	Statute Inches to One Sec. Ft.
2738	6.025	2.002	12	2	.348	.346	.345	34.8
2739	6.028	2.004	12	2	.347	.345	.345	
2740	6.053	2.005	12	4	.347	.343	.343	35.0
2741	6.053	2.005	12	4	.346	.342	.343	
2745	6.059	2.002	12	6	.344	.340	.341	35.2
2746	6.059	2.002	12	6	.343	.339	.341	
2751	6.068	2.000	12	8	.352	.348	.346	34.7
2752	6.068	2.000	12	8	.351	.347	.346	
2777	6.058	2.005	12	14	.343	.339	.338	35.5
2778	6.058	2.005	12	14	.341	.337	.338	
2791	6.052	2.000	12	16	.359	.356	.356	33.7
2792	6.052	2.000	12	16	.360	.357	.356	
2807	6.034	2.004	12	16	.358	.355	.354	33.9
2809	6.034	2.004	12	16	.357	.354	.354	
2743	6.040	3.995	24	4	.647	.643	.643	37.3
2744	6.040	3.995	24	4	.646	.643	.643	
2747	6.042	3.997	24	6	.658	.654	.653	36.8
2748	6.041	3.999	24	6	.656	.652	.653	
2753	6.057	4.002	24	8	.664	.657	.658	36.5
2754	6.057	4.002	24	8	.664	.657	.658	
2759	6.062	3.998	24	10	.666	.659	.661	36.3
2760	6.062	3.998	24	10	.667	.660	.661	
2767	6.072	4.001	24	12	.672	.664	.664	36.1
2768	6.072	4.001	24	12	.673	.665	.664	
2779	6.058	3.999	24	14	.665	.659	.658	36.5
2780	6.058	3.999	24	14	.663	.657	.658	
2793	6.054	4.004	24	16	.671	.664	.663	36.2
2794	6.054	4.004	24	16	.670	.663	.663	

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TABLE 1.—Continued.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES (TUBE BOX).

No. of Experiment	Orifice: D Depth in Inches	Orifice: B Breadth in Inches	Orifice: Nominal Area in Sq. Inches	Width of Box Inches	Discharge in Cubic Feet per Sec.: Observed By Experiment	Discharge in Cubic Feet per Sec.: Correct'd for Nominal Area	Discharge in Cubic Feet per Sec.: Curve Value	Statute Inches to One Sec. Ft.
2749	6.036	6.002	36	6	.953	.947	.945	38.1
2750	6.036	6.002	36	6	.950	.944	.945	
2755	6.051	6.000	36	8	.969	.961	.963	37.4
2756	6.051	6.000	36	8	.970	.962	.963	
2761	6.061	6.002	36	10	.985	.975	.970	37.1
2762	6.061	6.002	36	10	.984	.974	.970	
2769	6.068	6.000	36	12	.986	.975	.976	36.9
2770	6.068	6.000	36	12	.986	.975	.976	
2781	6.061	6.001	36	14	.991	.981	.991	36.3
2782	6.061	6.001	36	14	.989	.979	.991	
2795	6.046	6.001	36	16	.986	.978	.978	36.8
2796	6.046	6.001	36	16	.987	.979	.978	
2757	6.039	8.003	48	8	1.265	1.256	1.252	38.3
2758	6.039	8.003	48	8	1.258	1.249	1.252	
2763	6.054	7.999	48	10	1.285	1.274	1.275	37.6
2764	6.054	7.999	48	10	1.287	1.276	1.275	
2771	6.068	7.998	48	12	1.299	1.285	1.283	37.4
2772	6.068	7.998	48	12	1.296	1.282	1.283	
2783	6.063	8.001	48	14	1.309	1.295	1.291	37.2
2784	6.063	8.001	48	14	1.306	1.292	1.291	
2797	6.050	8.008	48	16	1.301	1.289	1.286	37.3
2798	6.050	8.008	48	16	1.298	1.286	1.286	
2765	6.054	10.004	60	10	1.576	1.561	1.565	38.3
2766	6.054	10.004	60	10	1.586	1.571	1.565	
2773	6.064	10.003	60	12	1.602	1.585	1.586	37.8
2774	6.064	10.003	60	12	1.601	1.584	1.586	
2785	6.068	9.998	60	14	1.603	1.585	1.594	37.6
2786	6.068	9.998	60	14	1.606	1.588	1.594	
2799	6.054	10.004	60	16	1.612	1.597	1.596	37.6
2800	6.054	10.004	60	16	1.607	1.592	1.596	
2775	6.063	12.004	72	12	1.892	1.872	1.873	38.4
2776	6.063	12.004	72	12	1.894	1.874	1.873	
2787	6.073	12.007	72	14	1.931	1.907	1.896	38.0
2788	6.073	12.007	72	14	1.929	1.905	1.896	
2801	6.054	12.000	72	16	1.915	1.898	1.898	37.9
2802	6.054	12.000	72	16	1.916	1.899	1.898	
2789	6.077	14.002	84	14	2.218	2.190	2.190	38.4
2790	6.077	14.002	84	14	2.219	2.191	2.190	
2803	6.058	14.004	84	16	2.234	2.212	2.206	38.1
2804	6.058	14.004	84	16	2.222	2.200	2.206	
2805	6.060	15.996	96	16	2.543	2.518	2.520	38.1
2806	6.060	15.996	96	16	2.547	2.522	2.520	

The discharge for each size of orifice and box is given in second feet in the next to the last column in table 1, and the number of statute

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inches equal to one second foot is given in the last column. It will be seen that, in general, the discharge for any certain size of orifice increases as the width of the box is increased, except for a slight reduction when the orifice is nearly the same size as the box. The number of statute inches to one second foot therefore decreases with a decrease in the size of the box, and it will also be noticed that the number of statute inches to one second foot increases as the size of the orifice is increased, which means that the discharge of each square inch of orifice decreases as the size of the orifice is increased. This is the opposite to the results obtained with thin-edged orifices having free flow, as given in tables 2 and 3. Box-tubes with orifices from 12 to 96 square inches gave discharges with the number of statute inches to one second foot varying from 33.7 to 38.4, and a greater number would no doubt be obtained for still larger orifices.

Thin-Edged Orifices With Free Flow.—A large majority of the present day Miner's Inch devices have a thin-edged orifice placed in the vertical side of a box, so the water passes into the air as it flows through the orifice. Experiments were made with this type of orifice in sizes ranging from 1 inch square to 6 inches deep by 16 inches wide. The depth of water above the top of the orifice was five inches in every case. The brass orifice taples were placed in the end of a concrete box having a cross-section of 10 feet by 6 feet deep. The experimental results are given in tables 2 and 3.

TABLE 2.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES.
(Thin edged orifices.)

No. of Experiment	Orifice		Nominal area in Sq. Inches	Discharge in Cubic Feet Per Sec.		
	D Depth in Inches	B Breadth in Inches		Observed by experiment	Corrected for Nominal area	Curve Values
1395	1.005	1.004	1	.024	.024	.024
1396	1.005	1.004	1	.024	.024	.024
1393	1.000	2.003	2	.047	.047	.047
1394	1.000	2.003	2	.047	.047	.047
1387	1.005	3.011	3	.072	.071	.071
1388	1.005	3.011	3	.072	.071	.071
1385	1.000	4.003	4	.095	.095	.095
1386	1.000	4.003	4	.095	.095	095
1379	1.005	5.000	5	.119	.118	.118
1380	1.005	5.000	5	.119	.118	118
1391	2.003	1.000	2	.049	.049	.049
1392	2.003	1.000	2	.049	.049	.049
1377	2.006	2.001	4	.096	.096	.097
1378	2.006	2.001	4	.097	.097	.097
1373	2.001	2.998	6	.145	.145	.145
1374	2.001	2.998	6	.145	.145	.145
1369	2.005	4.004	8	.194	.193	.193
1370	2.005	4.004	8	.194	.193	.193
1365	2.009	5.007	10	.243	.242	.242
1366	2.009	5.007	10	.243	.242	.242

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TABLE 2.—Continued.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES.

(Thin edged orifices.)

No. of Experiment	Orifice		Nominal area in Sq. Inches	Discharge in Cubic Feet Per Sec.		
	D Depth in Inches	B Breadth in Inches		Observed by experiment	Corrected for Nominal area	Curve Values
1389	3.011	1.005	3	.077	.076	.076
1390	3.011	1.005	3	.077	.076	.076
1375	2.998	2.001	6	.150	.150	.150
1376	2.998	2.001	6	.149	.149	.150
1363	3.018	3.005	9	.227	.225	.223
1364	3.018	3.005	9	.227	.225	.223
1359	3.002	4.008	12	.299	.298	.298
1360	3.002	4.008	12	.299	.298	.298
1355	3.007	5.033	15	.378	.375	.375
1356	3.007	5.033	15	.378	.375	.375
1383	4.003	1.000	4	.106	.106	.105
1384	4.003	1.000	4	.105	.105	.105
1371	4.004	2.005	8	.208	.207	.207
1372	4.004	2.005	8	.208	.207	.207
1361	4.008	3.002	12	.313	.312	.309
1362	4.008	3.002	12	.310	.309	.309
1353	3.999	4.007	16	.411	.410	.410
1354	3.999	4.007	16	.411	.410	.410
1349	4.005	5.020	20	.515	.512	.513
1350	4.005	5.020	20	.515	.512	.513
1381	5.000	1.005	5	.137	.136	.137
1382	5.000	1.005	5	.138	.137	.137
1367	5.007	2.009	10	.271	.269	.268
1368	5.007	2.009	10	.271	.269	.268
1357	5.033	3.007	15	.403	.399	.398
1358	5.033	3.007	15	.401	.397	.398
1351	5.020	4.005	20	.533	.530	.530
1352	5.020	4.005	20	.529	.526	.530
1347	5.014	5.006	25	.663	.660	.662
1348	5.014	5.006	25	.665	.662	.662
1345	6.006	2.005	12	.331	.330	.332
1346	6.006	2.005	12	.333	.332	.332
1343	6.006	3.998	24	.652	.652	.650
1344	6.006	3.998	24	.651	.651	.650
1341	6.006	6.002	36	.975	.974	.972
1342	6.006	6.006	36	.982	.981	.972
1339	6.006	7.997	48	1.306	1.305	1.302
1340	6.006	7.997	48	1.308	1.307	1.302
1337	6.006	9.995	60	1.636	1.635	1.634
1338	6.006	9.995	60	1.637	1.636	1.634
1335	6.006	11.997	72	1.968	1.967	1.970
1336	6.006	11.997	72	1.972	1.971	1.970
1333	6.006	13.997	84	2.303	2.301	2.304
1334	6.006	13.997	84	2.301	2.299	2.304
1331	6.006	15.998	96	2.645	2.643	2.641
1332	6.006	15.998	96	2.640	2.638	2.641
2335	12.069	12.066	144	4.588	4.587	
2336	12.069	12.066	144	4.577	4.526	

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TABLE 3.

DISCHARGE THROUGH MINER'S INCH ORIFICES OF VARIOUS SIZES*

†B	‡D—1 Inch			D—2 Inches			D—3 Inches			D—4 Inches			D—5 Inches			D—6 Inches		
	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.
1....	.024	.0240	41.7	.049	.0245	40.8	.076	.0253	39.5	.105	.0262	38.1	.137	.0273	36.6	.169	.0282	35.5
2....	.047	.0235	42.6	.097	.0243	41.2	.150	.0250	40.0	.207	.0259	38.7	.268	.0268	37.3	.331	.0276	36.3
3....	.070	.0233	42.9	.145	.0242	41.4	.223	.0248	40.4	.309	.0257	38.8	.398	.0265	37.7	.491	.0273	36.7
4....	.094	.0235	42.6	.193	.0241	41.5	.298	.0248	40.3	.410	.0256	39.0	.530	.0265	37.7	.650	.0271	36.9
5....	.118	.0236	42.4	.242	.0242	41.3	.375	.0250	40.0	.513	.0257	39.0	.662	.0265	37.8	.810	.0270	37.0
6....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.973	.0270	37.0
7....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.14	.0271	36.9
8....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.30	.0271	36.9
9....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.47	.0272	36.8
10....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.64	.0273	36.7
11....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.80	.0273	36.6
12....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.97	.0274	36.6
13....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.14	.0274	36.5
14....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.30	.0274	36.5
15....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.47	.0275	36.4
16....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.64	.0275	36.3

*Shapes of orifices conform to Colorado Statute. Head was 5 inches above top of orifice opening in all cases.

†B—Breadth or horizontal dimension of orifice in inches.

‡D—Depth or vertical dimension of orifice in inches.

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Table 3 shows some interesting points. The discharge for each square inch of opening increases as the size of the opening is increased. For a constant depth of orifice the discharge per square inch of opening is the greatest for a width of 1 inch, decreases as the width is increased for a few inches, or approximately until the orifice is square for the larger sizes of orifices, and then increases as the width is increased. The number of Statute Inches to one second-foot varies from 42.9 to 35.5, but for the sizes of orifices commonly used, for measuring water to the individual irrigator, it is probable the value would be from 36 to 37, and as low as 35 might be obtained for wider orifices. The discharges given in table 3 are probably the least quantities that can be obtained for orifices of that type, because they were thin-edged, the velocity of approach was negligible, and the contractions were complete.

The discharge through full contraction, thin-edged, free-flow orifices having a depth or vertical dimension of 6 inches and a head of 5 inches above the top of the orifice, is represented by the formula,

$$Q = 0.169b - 0.06 + \frac{0.06}{1 + 0.015\ b^{2.6}}$$

in which Q is in second-feet, and b is the breadth or horizontal dimension of the orifice in inches.

Uncompahgre Orifice.—The type of orifice shown in figures 1 and 2 has been used for years on some of the canal systems now included in the Uncompahgre project of the U. S. Reclamation Service, and they conform to the Colorado Inch law in all respects as long as a 5-inch depth of water is maintained over the top of the orifice. The side of the box in which the orfice is placed is made 5 inches higher than the top of the orifice for a length of 5 feet, which acts as a spillway to regulate the head, but it is occasionally necessary to run a greater or less amount of water for short periods. When necessary to deliver 90 or 75 per cent of the full head temporarily the depth of water in the box will decrease as the depth decreases in the ditch, which saves changing the size of all of the orifices and they act somewhat as proportional dividers of the flow because all of the boxes on a ditch are set under almost identical conditions. When the supply of water in the ditch is greater than normal, the boxes act as spill-boxes. Mr. F. D. Pyle, manager of the Uncompahgre Project, has added a heavy galvanized iron orifice plate to the original device. The orifice is 6 inches deep and is provided with a slide which moves horizontally. Holes punched through the orifice plate and slide allow the slide to be set for each 0.05 second-foot up to 2 second feet and a padlock placed through the hole prevents the size of the orifice being tampered with after it is set by the ditch rider. Graduations on the side of the orifice indicate its discharge when operating as a weir.

The discharges through the Uncompahgre orifice under various conditions are given in table 4. Although the original water-rights are expressed in inches, the water is delivered in second-feet. By comparing tables 3 and 4 it will be seen that the discharge is greater through the

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TABLE 4.

DISCHARGE FROM UNCOMPAHGRE ORIFICE IN CUBIC FEET PER SECOND

Width of Opening in Inches.	Depth of Water Surface to Bottom of Orifice Opening in Inches.																				
	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
2	.04	.05	.07	.09	.11	.13	.15	.17	.20	.22	.24	.25	.27	.29	.30	.31	.32	.34	.35	.36	.37
2½	.05	.06	.08	.10	.13	.16	.19	.21	.24	.27	.30	.32	.34	.36	.38	.40	.41	.42	.43	.44	.45
3	.06	.08	.10	.13	.16	.19	.22	.26	.29	.33	.36	.38	.40	.43	.45	.47	.49	.51	.52	.53	.54
3½	.06	.09	.12	.15	.18	.22	.26	.30	.34	.38	.42	.45	.47	.50	.53	.55	.57	.59	.61	.62	.63
4	.07	.10	.13	.17	.21	.25	.29	.34	.39	.43	.47	.51	.54	.57	.60	.63	.65	.67	.69	.71	.72
4½	.08	.11	.15	.19	.23	.28	.33	.38	.43	.48	.53	.57	.60	.64	.67	.70	.73	.76	.78	.80	.82
5	.08	.11	.15	.19	.23	.31	.33	.38	.43	.48	.59	.63	.67	.71	.74	.78	.81	.84	.86	.89	.91
5½	.10	.14	.18	.23	.28	.34	.40	.46	.52	.59	.65	.69	.73	.78	.82	.86	.89	.92	.95	.98	1.00
6	.11	.15	.20	.25	.30	.36	.43	.50	.56	.64	.70	.75	.80	.85	.89	.93	.97	1.00	1.03	1.06	1.09
6½	.12	.16	.21	.27	.33	.39	.46	.54	.61	.69	.76	.81	.86	.91	.96	1.00	1.04	1.08	1.12	1.15	1.18
7	.13	.18	.23	.29	.35	.42	.50	.57	.65	.74	.81	.87	.92	.98	1.03	1.08	1.12	1.16	1.20	1.24	1.28
7½	.14	.19	.25	.31	.38	.45	.53	.61	.69	.79	.87	.93	.98	1.04	1.10	1.15	1.20	1.25	1.29	1.33	1.37
8	.14	.20	.26	.33	.40	.48	.56	.64	.73	.83	.92	.99	1.05	1.11	1.17	1.23	1.28	1.33	1.37	1.42	1.46
8½	.15	.21	.28	.35	.42	.50	.59	.68	.78	.88	.97	1.05	1.11	1.18	1.24	1.30	1.36	1.41	1.46	1.51	1.56
9	.16	.22	.29	.37	.44	.53	.63	.72	.82	.93	1.02	1.10	1.17	1.24	1.31	1.37	1.43	1.49	1.54	1.60	1.65
9½	.17	.24	.31	.39	.47	.56	.66	.76	.86	.97	1.07	1.16	1.23	1.31	1.38	1.45	1.51	1.57	1.63	1.69	1.74
10	.18	.25	.33	.41	.49	.59	.69	.79	.90	1.02	1.13	1.22	1.30	1.38	1.45	1.52	1.59	1.65	1.71	1.77	1.83
10½	.19	.27	.34	.43	.51	.61	.72	.83	.94	1.07	1.18	1.28	1.36	1.44	1.51	1.59	1.66	1.73	1.79	1.85	1.91
11	.20	.28	.36	.45	.54	.64	.75	.87	.99	1.12	1.23	1.33	1.42	1.50	1.58	1.66	1.73	1.80	1.87	1.94	2.00
11½	.21	.29	.38	.46	.56	.67	.78	.90	1.03	1.16	1.28	1.38	1.48	1.57	1.65	1.73	1.81	1.88	1.95	2.02	2.09
12	.22	.30	.39	.48	.58	.69	.81	.94	1.07	1.21	1.33	1.44	1.54	1.63	1.72	1.80	1.88	1.96	2.03	2.10	2.17

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Uncompahgre orifice, because of the comparatively high velocity of approach in the orifice box. Orifices are used for delivering only a part of the water under this project, rectangular weirs being also used.

Figure 1. (a) Showing the usual method of placing an Uncompahgre orifice box in a ditch.

Figure 1. (b) Side view of Uncompahgre orifice spill-box.

AZUSA HYDRANT.

Where the price of irrigation water is high, as in Southern California, it is often desirable to do away with surface ditches and conduct the water to the land through underground pipes. This decreases the loss of water by seepage and evaporation, permits all of the land to be cultivated, and is especially desirable for orchard irrigation. The water is brought to the surface of the ground by standpipes which are arranged to deliver the water to several furrows. There are several

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different kinds of measuring devices used in connection with underground pipe systems, but only one was experimented with.

The Azusa hydrant is used in the vicinity of Azusa, California. The essential features are shown in figure 3, and the details of the orifices are shown in figure 4. It consists of a concrete box about 6 feet high placed in the supply pipe line, with the orifice plate set in the side of the box so the tops of the orifices are 12 inches below the top of the box. An overflow crest placed on the top of a dividing wall in the box is 2 inches above the top of the orifices. The flow through the orifices is regulated by a gate in the dividing wall near the floor. There are 4 orifices each 4 inches deep and of different widths which are supposed to deliver 10, 15, 25 and 50 miner's inches upon the basis of 50 miner's inches to 1 second foot and they may be used singly or in a combination. The orifice plate is made of cast iron carefully machined.

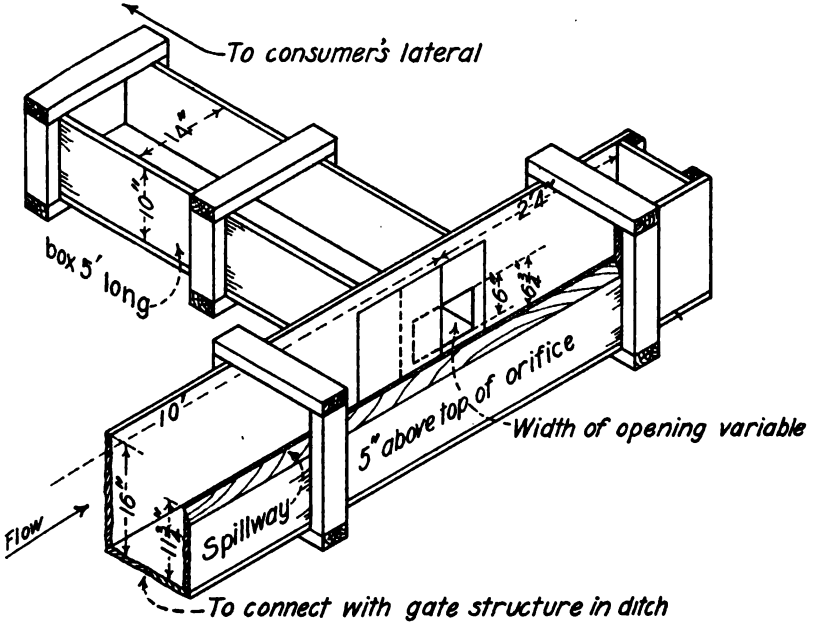

Figure 2. Some details of the Uncompahgre orifice.

The results of the experiments with the Azusa hydrant given in table 5, indicate the actual discharges to be from 2.0 to 6.4 percent less than the intended discharges. Table 6 gives the dimensions of orifices which will discharge the intended number of miner's inches. However, in actual practice the orifices become larger, due to the edges rusting, and the head of water is usually greater than 2 inches because a small amount is allowed to pass over the spillway or overflow.

In Bulletin 247 of the California Expkeriment Station, Mr. Frank Adams states the cost of the Azusa hydrant to be from $18 to $20 under a large contract, and about $30 when built singly. The orifice plate costs an additional $12.

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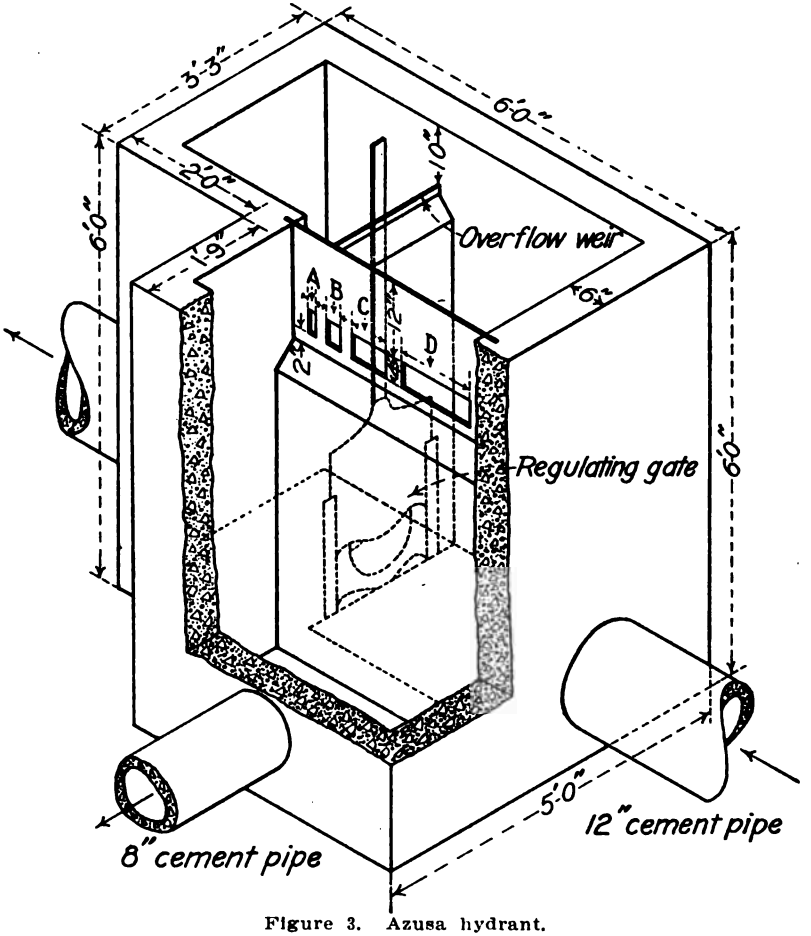

Figure 3. Azusa hydrant.

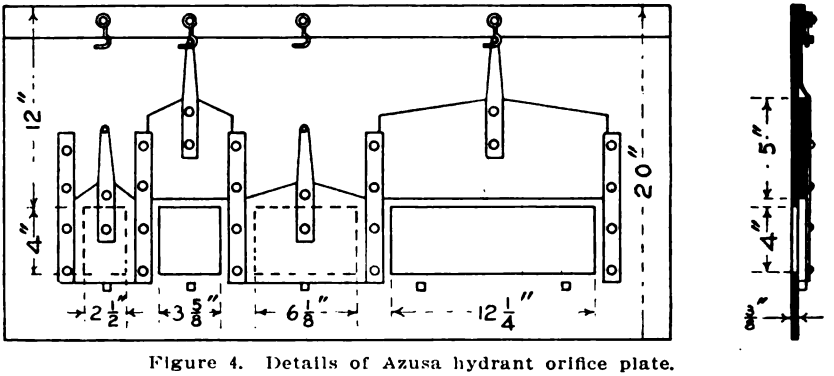

Figure 4. Details of Azusa hydrant orifice plate.

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TABLE 5.
RESULTS OF EXPERIMENTS WITH AZUSA HYDRANT.

Opening	Actual Area of Opening in Square Inches	Actual Discharge in Cubic Feet per Second	Discharge in Miner's Inches Corrected for Nominal Area	Intended Discharge in Miner's Inches	Percent* of Error
A	9.991	.195	9.8	10	2.0
B	14.488	.281	14.1	15	6.4
C	24.494	.474	23.7	25	5.5
D	49.008	.967	48.4	50	3.3
A+B	24.479	.478	23.9	25	4.6
A+B+C	48.973	.959	48.0	50	4.2
A+B+C+D ..	97.981	1.925	96.3	100	3.8
A+B+D	73.487	1.439	72.0	75	4.2
A+C	34.485	.668	33.4	35	4.8
A+C+D	83.493	1.641	82.1	85	3.5
A+D	58.999	1.157	57.9	60	3.6
B+C	38.982	.762	38.1	40	5.0
B+C+D	87.990	1.729	86.5	90	4.1
B+D	63.496	1.248	62.4	65	4.2
C+D	73.502	1.451	72.6	75	3.3

* Percent of Error between intended discharge and correct discharge in Miners' inches, using the correct discharge as the basis. The Miners' Inch was taken as 1-50 cubic foot per second, which is Southern California practice.

TABLE 6.
WIDTH OF OPENINGS TO GIVE THE INTENDED DISCHARGE WITH AZUSA HYDRANT.

Opening	Depth in Inches	Width in Inches	Discharge in Miner's Inches*
A	4	2 9-16	10
B	4	3 ⅞	15
C	4	6 15-32	25
D	4	12 ⅝	50

* Southern California inch, which is 1-50 cu. ft. per sec.

SUMMARY.

The value of the Colorado Statute Inch has been assumed to be 1/38.4 part of a cubic foot per second, and this figure has been commonly used for years. It is not a legal definition of the Statute Inch and may be in error as shown in tables 1, 2 and 3. The number of Statute Inches to the second foot may vary from at least 33.7 to 42.9 and still conform to the law in every particular. Although the use of the Statute Inch is somewhat limited at the present time, it is used in connection with interpreting water rights, and it would be well to have its value fixed by law as a definite part of a second foot.

The discharges obtained in these experiments are probably less than would be obtained in actual practice where one or more of the following conditions are usually found, and they all tend to increase the flow through an orifice: thick edges, such as an opening cut in a plank without outward bevel to the edges; rounding edges; velocity of approach which would be caused by an orifice placed in a small box, or an accumulation of sand which would reduce the distance from the bottom of the

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orifice to bottom of the box; an appreciably greater head due to the depth of water pouring over the spill-crest.

Some of the Miner's Inch measuring devices are well adapted to the conditions under which they are used. They are especially applicable to the measurement of small flows of water and when used in connection with a spill-box they act somewhat as a proportional divider. They are not well suited to the rotation method of delivery of water where large quantities are delivered for short periods, and they will not deliver a flow much in excess of their normal capacity. These measuring devices are often unjustly condemned, for the fault is not with the orifice structures as much as with the unit of measurement used, the Inch, whether it be called Miner's, Statute, Customary, or Farmer's Inch. These orifices are reasonably accurate in their measurement of water, but they should be calibrated or built according to plans which will give a known discharge, and this discharge should be expressed in cubic feet per second or some other equally definite quantity.

UNITS OF MEASURE.

The Cubic Foot Per Second, called second-foot, is a unit of measure for flowing water. When a stream discharges 1 cubic foot of water in one second, there is a second-foot flow.

The Acre-Foot is a unit of measure for standing water, and is that volume which will cover one acre one foot deep. An acre-inch is one-twelfth of an acre-foot, or the volume which will cover one acre to a depth of one inch.

The Miner's Inch is unsatisfactory and rapidly losing favor as a unit for measuring water, because it is not a definite quantity. It varies with the conditions under which it is used, and is therefore being replaced by the second-foot. In several of the Western states the Miner's Inch has been defined by law as being a certain fractional part of a second-foot, and these values are given in the accompanying table of Hydraulic Equivalents.

TABLE OF HYDRAULIC EQUIVALENTS.

1 cubic foot equals 7.48 gallons, or approximately 7½ gallons.

1 cubic foot of water weighs approximately 62½ pounds.

1 cubic foot per second equals 448.83 gallons per minute, or approximately 450 gallons per minute.

1 cubic foot per second flowing for 1 hour equals approximately 1 acre-inch.

1 cubic foot per second flowing for 12 hours equals approximately 1 acre-foot.

1 cubic foot per second flowing for 24 hours equals approximately 2 acre-feet.

1 acre foot equals 43,560 cubic feet, equals 325,851 gallons.

1,000,000 cubic feet (1 million cu. ft.) equals 22.95 acre-feet.

In California, Nevada, and Montana, 1 Miner's Inch (Statutory Inch) equals 1-40 of 1 cubic foot per second.

In Utah, Idaho, Arizona, and New Mexico, 1 Miner's Inch (Statutory Inch) equals 1-50 of one cubic foot per second.

In Colorado it has been generally assumed that 1 Miner's Inch (Statutory Inch) equals 1-38.4 of one cubic foot per second.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART I

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FORT COLLINS, COLORADO
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A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART I

It is generally conceded that the flour made from Colorado wheat is inferior to that made from Kansas hard wheat or the better grades of Minnesota flour. Such is the opinion of the bakers and of the public. I have made inquiry regarding the difference in the bread-yield between Kansas and Colorado flours on the supposition that they were equally well milled. As nearly as I can learn, there is a difference of from 30 to 40 loaves per barrel.

Having established the fact that soil conditions are, in the main, responsible for the characteristic properties of our sugar beets, it seemed advisable to study our wheat crop to find out if possible, the factors that determine the quality of our Colorado wheats. In beginning this work, we assume that the popular estimate of our wheat for the purpose of bread-making, i. e., that it is inferior to the best, is established.

In looking over the literature we find no published results of work done on Colorado wheats since the early eighties. Mr. Clifford Richardson published in the Report U. S. Department of Agriculture, 1883, forty-five analyses of Colorado Wheats. Protein (Nx6.25) ran from 11.0 to 15.94, average 13.27, and in the Report of 1884, sixty-one analyses. The protein ranged from 8.93 to 14.00, average 11.79 percent. The average of eleven Minnesota samples in 1883 Report is 12.4 percent, with one as high as 17.15 percent, and for fourteen Minnesota samples in the Report of 1884 the protein is 15.14 percent. The Colorado samples recorded seem to have been furnished by Prof. Blount, at that time Professor of Agriculture in this institution. In the Report of the U. S. Department of Agriculture for 1885 there is reference made to the low protein content shown in the results published in 1884. The statement is made that the low protein content was due to a storm which knocked down the plants and prevented the assimilation of nitrogen. It seems that the average nitrogen content of the sixty-one samples analyzed was 1.8864 percent which, so far as the amount is concerned, by no means calls for any apology and it matters little whether the reason assigned for its being lower than for the previous year, 2.00 percent, is correct or not. While Mr. Richardson's analyses are now upwards of thirty years old, they are probably as serviceable as they ever were, still we have deemed it advisable to

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make analyses of our own wheats, grown under conditions which we have varied to suit the purposes that we have had in view.

This bulletin will deal largely with the composition of our Colorado wheats, but more particularly with those factors which establish its quality or characteristics. It is evident from the analyses published that the Colorado wheats are, as a rule, as rich in nitrogen as other wheats. They compare favorably with the Minnesota wheats in nitrogen content and in other analytical respects, but the flour does not make as much bread as the Minnesota flour, at least this is the claim of our bakers. Whether it is justified or not, it is customary to consider the crude protein as an index of the quality of the wheat. There are many statements made which cast doubt upon the correctness of this practice. Still it is almost universal, and a high-protein wheat is considered a good wheat. Our wheats are rich enough in protein, but they are considered soft or weak wheats. The object of our study is to discover if possible the factor or factors in our conditions on which this inferiority depends. Our primary assumption is that our climatic conditions are favorable, the vegetative period of the wheat is usually short, our summers are warm and the sunshine practically constant. We do not have excessive quantities of rain, and irrigation is necessary, except occasionally, when the winter wheat may make a good crop without irrigation.

The amount of winter wheat grown in the irrigated sections of the State forms only a small portion of the total, so the wheat of chief importance is the spring wheat.

The climatic conditions are such that we should expect wheat of high quality; the temperature is sufficiently high and uniform, the nights are cool, the rainfall small, the water supply largely under our control, while the sunshine is practically constant and fogs are so good as unknown.

Our soils are easily cultivated, at least for the greater part. They are also well supplied with plant food and yield excellent crops. I have no statistics at hand whereby to establish the average crop on our irrigated lands, but from such information as I have obtained, I think that the average of spring wheat on such lands will not fall so low as 30 bushels, and in many years it will be better than 35 bushels. The kernels are usually plump, but sometimes shrunken; they are apt to lack in flintiness; in this respect, however, they vary. Some land produces very mealy wheat while other lands under the same climatic conditions produce flinty wheat. By far, the greater portion of our wheat that I have seen is mixed, that is, contains both characters of berries. This condition is not peculiar to Colorado. It is present in almost every sample of wheat, spring or win-

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ter, that I have seen, and in many of them it is very prevalent. I have treated of this condition, designated as Yellow-berry, in Bulletin 205 of this Station.

Yellow-berry wheat is considered as in some way deteriorated wheat. I do not think that this opinion has been shown to be based upon any established facts. The only justification that I know of for it, is the fact that such wheats, or rather kernels, are lower in nitrogen than flinty kernels when grown on the same plot of ground. It may be true that the flinty berries, richer in nitrogen, actually make a better flour than the yellow-berry kernels but, up to the present time, I think that this is inferred rather than proved. While writers, with almost no exception, assume that a high protein content in wheat indicates a strong wheat, the most of them at the same time insist that the quality of the gluten and not its quantity is determinative of the value of the flour for bread-making purposes. Colorado wheats are not deficient in nitrogen according to the information at present obtainable; even those samples affected with yellow-berry, while lower in nitrogen than samples containing only flinty berries, are not so deficient as to indicate inferiority in the essential quality of break-making. The inference, so far as I have been able to ascertain, has not even been based upon the lower nitrogen content, but is a general assertion based upon the assumption that the yellow-berry is an abnormality.

The Californian wheats are generally spoken of as soft, weak wheats, but are commended for their color and flavor. We find the nitrogen content given for Club, 2.064; White Australian, 1.936; and Propo, 1.918 percent.* These figures are as high as we find given for the hard wheats.

In comparing data concerning protein present it is to be remembered that all of the older data is based on the factor 6.25, while much of the more recent data is based on the factor 5.7. The former makes the protein 1.1 times as much as the latter.

Notwithstanding the fair percentage of nitrogen present in our Colorado wheats, the general experience is that it is not of high bread-making qualities. The second task that we set ourselves in this bulletin is to determine the properties and characteristics of our wheats as they are produced for the markets. We shall first consider our soil conditions and the effects of the individual elements, nitrogen, phosphorus and potassium.

We shall use the term "weak wheat" to designate one which yields a flour of low bread-making quality without regard to whether it is soft or hard and we shall use the term "soft" to indicate a wheat whose kernels crush easily without regard to its bread-making quality—so we shall have the two pairs of characters, weak and

*California Bulletin 212, p. 366.

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strong, soft and hard. These may be synonomous terms, but not necessarily so, though we find them so used.

The plan of our work includes field experiments in which we cannot control all of the conditions, and later a series of experiments in which we can control all of the conditions. By means of the field experiments we hope to ascertain what the normal characteristics of our wheat really are, both in regard to composition and to the bread-making qualities of the flour produced. We found at the very beginning that this phase of our work required much more extended experimentation than we really desired to undertake, but it was unavoidable. Besides, this seemed to be the only way to analyze the effects of the individual fertilizers usually applied in agriculture, i. e., nitrogen, phosphorus and potassium, and in our case a fourth element, largely under our control, water. Concerning the effects of these elements upon the character, composition and properties of wheat, little seems to have been done. The effects upon the yield have been studied. Some observations have also been made upon the part that the time of application plays in the yield and properties of the grain, this is especially true of the nitrogen; but these observations have been incidental to the experiments rather than a main object. We have been unable to study these points as we wished to; this is especially true in regard to the effects of the water applied. We have been exceedingly fortunate, however, in obtaining samples of wheat grown under controlled conditions so far as the application of water is concerned which answer our purposes just as well as though we had made the experiments ourselves.

We have applied the three fertilizers, nitrogen, phosphorus and potassium, in different quantities. The latter two were added at one time, but the nitrogen was not. The nitrogen work consisted of three series of experiments, in which the minimum quantity of nitrogen used was applied to all of the plots at the same time. Two of the series subsequently received another application, so that one series received a minimum amount, one series received twice and one three times the minimum amount.

So far as the relative amounts are concerned, these ratios are true for the phosphorus and potassium, but the total amount was applied at the time of planting.

The cultivation of the soil was another point necessary to consider. The land used is not virgin soil, but has been under cultivation probably as long as most of our lands, an estimate of between 35 and 40 years would probably be correct. Deep cultivation of our prairie soils is not usually practiced. This is a result of experience on the part of the early settlers, who found that they obtained the

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best results by shallow plowing. The result of this in our case was that the land, to any depth greater than an average of six inches, was as firm as it had ever been with a slight plow sole at about six inches. My aim was to plow this land to the greatest feasible depth and subsoil it to a depth of eighteen inches in the fall of 1912, allow it to mellow and settle during the ensuing winter and plant it in the spring. I was not able to get this done, so I was compelled to plow and subsoil in the spring. As the season was quite wet, this made my planting late. Of the three sections of land on which I am making my experiments, I turned two of them to a depth of twelve inches and subsoiled four inches deeper, sixteen inches in all. The other section was turned to a depth of nine inches but was not subsoiled. All the advantages of fall plowing were lost, but I saw no disadvantages in the mechanical condition of the seed bed arising from the spring working of the soil. I did not do this spring plowing because I wished to, but because I had to begin some time to get the land in the condition that I desired.

This plowing turned up some six inches of subsoil and put it on top. Ordinarily this would be very disadvantageous, but in our case the subsoil is capable of making just as kind a soil as the surface portions, as there is no very great difference between the soil and subsoil from a chemical standpoint, but from a biological standpoint there is a very great difference in favor of the surface soil. So far as this feature was concerned, my deep turning of the soil was decidedly disadvantageous, but in another respect it was very much to my advantage. This land had been planted to oats and barley the preceding season; both crops had grown luxuriantly, lodged badly, were harvested late and there was a very heavy loss of grain. Even with my deep plowing there were many spots where the oats and barley crowded out the wheat. Had it not been for the deep plowing the oats and barley would have been very much worse. This land is a somewhat clayey loam with visible deposition of calcium carbonate and sulfate below the depth to which it previously had been plowed. On irrigating, it takes water readily, and on drying cracks badly. This last factor cannot fail to be of considerable importance, for these cracks often gape open as much as one-half or even three-quarters of an inch and extend into the ground for several inches. Many of them are as much as four inches deep. I cannot state that I saw any decidedly injurious effects from this cracking, but the segments of soil formed or separated from one another by these cracks dry out rapidly.

We made no study of the bacteriology of the soil but we know that the surface soil that we turned under possessed a decided ability to fix nitrogen and convert it into nitrates. From this stand-

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point the deep plowing was a decided disadvantage, if we may judge from the bacterial counts made on samples of this soil compared with those made on samples of soil from the same field which had not been plowed so deep.

The only object which I had in breaking up this land was to put it into what I considered good condition. The other and principal immediate objects have been mentioned, one of them was advantageous and the other probably not. The former was the suppression of the barley and oats and the other the diminution of the bacterial flora of a beneficient character. While we have reason to believe that the occupation of the land by cultivated crops influences the bacterial activity in the soil, both by the removal of the products formed, and perhaps also by being directly inimical to their development, still such activity continues with greater or less intensity. In this particular soil we have found nitric nitrogen corresponding to 160 pounds of sodic nitrate in the surface two inches of the soil and 342 pounds in the first foot of soil. This was in fallow spots occurring in a stand of beets. Perhaps the results obtained with land after cropping, compared with land cultivated fallow, may be more acceptable. The cropped land had been planted to wheat which was harvested in early August. Immediately after harvest the stubble was irrigated and disked and allowed to rest till October when it was plowed and harrowed. The samples were taken from both sections 4 December. A part of the cropped land had received a dressing of phosphorus as superphosphate, and another of potassium as muriate. These facts make a very marked difference. The section cultivated fallow throughout the season contained nitric nitrogen equivalent to 518 pounds of sodic nitrate in the surface foot. The cropped land, which had received a dressing of phosphorus, contained 257 pounds of sodic nitrate taken to the same depth while that which had received the potassium contained 184 pounds. There is no question but that this is the result of fixation and nitrification in this soil and the differences show the effect of cropping on the one hand, though modified by the cultivation received after the removal of the crop, and cultivation fallow during the whole season on the other hand. The results also indicate the favorable effect of the application of phosphorus upon the bacterial activity of the soil. The application of 518 pounds of sodic nitrate per acre to wheat, immediately after sowing, would almost certainly lodge it and give small-grained, shrunken wheat, even if all other conditions were ideal. The consideration of these facts is important in our agriculture. I do not think that this question is as important to all other sections of this country as it is to us, but I believe it to be of very considerable importance to almost all sections

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of the State. While there is a question in regard to the application of observations made in one locality to the whole of so large a state as Colorado, to say nothing of other states, I still hold that they will. with little modification, be applicable to a very large portion of the west.

I learned much more by turning the land to a depth of twelve inches than I expected to and while I would not advise so radical a procedure as I adopted, the deep cultivation has not shown any disadvantage but on the contrary justifies itself in several ways.

This presents a general though incomplete outline of our field work and the special objects which we hoped to accomplish, *i. e.*, to produce wheat under field conditions on a sufficiently large scale to make the results thoroughly representative, and, through the study of these products to ascertain the properties and character of Colorado wheats. We further hope to control the cultural conditions in such manner that we may be able to establish the effects of nitrogen, phosphorus, potassium and irrigation upon the composition and quality of the wheat produced, and see if in any of these we find an explanation for the fact that our wheats do not produce as desirable a flour as Minnesota or Kansas wheats.

We have already shown in Bulletin 205, "Yellow-berry in Wheat; Its Cause and Prevention," that it is in our power to increase the yellow-berry or to suppress it and that the ratio between the available potassium and available nitrogen is the factor that determines the appearance of this characteristic. I studiously avoided making any assertion pertaining to the composition or quality of yellow-berry wheat in Bulletin 205 for the same reason that I now use the terms "weak wheats" and "soft wheats" with a more definite meaning than is usually done, and further for the very good reason that I did not know whether the yellow-berry, soft, starchy, mealy wheat is really inferior to the flinty, corneous or hard wheat or not. We left this question for discussion in the present bulletin. I adhered closely to the specific problem of the cause of yellow-berry and its prevention. This, however, is closely related to an important phase of my principal problems.

I stated that the growers could control the yellow-berry by increasing the nitrogen in the soil, as the cause is an undue proportion of available potassium compared with the available nitrogen. I also stated that one method of adding available nitrogen was to cultivate the land fallow; this statement applies to our conditions and I judge that it will apply very generally, but hesitate to make too broad a statement. The explanation that I offer is in the development of so large a quantity of nitrates in the soil that, though much may be washed beyond the reach of the plants or de-

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stroyed by reduction, there will still remain enough to counterbalance, for the one crop, the influence of the available potassium. This feature of the yellow-berry problem will be discussed further in this bulletin, and the composition and properties of such wheat will be treated of fully.

The experiments planned, consisted of three series with each of three varieties of wheat. Each series of experiments had four members including a check. The size of the plots was one-tenth of an acre. We made other experiments concurrently with these in which we used smaller plots. Casual reference may be made to these but they form no part of the series presented in this bulletin.

The soil chosen for these experiments varies some in character, but it is as nearly uniform as can ordinarily be obtained. The land is quite level and is easily irrigated. We have analyzed this soil, represented by samples taken from different portions of the field at various times. There are some differences, but whether they are great enough, compared with the total amount of the substances present, to justify one in giving them further consideration or not is a question. Absolute uniformity in areas of the size of the aggregate here used, about six acres, is not to be obtained. The mechanical and chemical analyses, including mass analyses of both the soil and subsoil, are given below.

There is but little use in discussing the amount of plant food present as indicated by the analyses, still it gives us a certain indefinite idea of abundance or lack of this food which, in a general way, may be of service. The amounts given are calculated for 8,000,000 pounds of soil, because the soil and subsoil together were taken to a depth of two feet. The total amount of potassic oxid present in this land taken to this depth is approximately 203,280 pounds, or 101.6 tons; of phosphoric acid, 16,080 pounds, 8 tons; of nitrogen, 8,240 pounds, 4¼ tons.

MECHANICAL ANALYSES OF THE SOIL AND SUBSOIL.

Size of Particles.	Soil Percent	Subsoil Percent
Over 1 mm	0.092	0.112
From 1 to 0.5 mm	0.865	0.456
From 0.5 to 0.25 mm	1.810	1.122
From 0.25 to 0.05 mm	45.790	49.883
From 0.05 to 0.01 mm	28.742	25.514
From 0.01 to Clay	10.062	9.617
Clay by difference	2.749	3.707
Moisture and organic matter	9.890	9.589
	100.000	100.000

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AGRICULTURAL ANALYSES OF SOILS AND SUBSOILS.

	Soil Percent	Subsoil Percent	Soil* Percent	Subsoil Percent
Insoluble	54.653	57.068	63.485	63.547
Silicic acid	19.805	12.754	9.865	8.558
Sulfuric acid	0.047	0.049	0.094	0.069
Phosphoric acid	0.120	0.127	0.175	0.160
Carbonic acid	3.048	6.312	2.976	4.942
Chlorin	0.032	0.059	0.025	0.035
Potassic oxid	0.872	0.742	0.715	0.578
Sodic oxid	0.290	0.432	0.408	0.316
Calcic oxid	6.100	8.465	4.725	7.310
Magnesic oxid	1.355	1.448	1.258	1.376
Ferric oxid	5.601	3.499	5.663	5.337
Aluminic oxid	3.738	5.397	3.563	2.738
Manganic oxid (M_3O_4)	0.118	0.026	0.175	0.160
Water at 100° C	.....	.....	2.816	2.111
Ignition	5.072	3.887	3.918	2.143
Sum	100.851	100.265	99.861	99.375
Oxygen equivalent to chlorin	0.007	0.013	0.005	0.007
Total	100.844	100.252	99.856	99.368
Total nitrogen	0.147	0.069	0.143	0.063
Humus	0.462	.....	0.675	0.262
Humus nitrogen	.....	.....	0.060	0.023
Humus ash	.....	.....	0.537	0.387
Water soluble	.....	.....	0.388	0.345
Potassic oxid sol. in citric acid	.....	.....	0.031	0.018
Phosphoric acid sol. in citric acid	.....	.....	0.021	0.015
Potassic oxid sol. in N-5 nitric acid	.....	.....	0.057	0.020
Phosphoric acid sol. in N-5 nitric acid	.....	.....	0.066	0.073

*This and its corresponding subsoil are composite samples.

MASS ANALYSIS OF SOIL AND SUBSOIL.

	Soil Percent	Subsoil Percent
Silicic acid	63.500	61.350
Sulfuric acid	0.446	0.178
Phosphoric acid	0.217	0.185
Carbonic acid	2.976	4.942
Chlorin	0.025	0.035
Potassic oxid	2.475	2.607
Sodic oxid	1.305	1.444
Calcic oxid	5.250	8.170
Magnesic oxid	1.680	1.796
Ferric oxid	6.263	5.805
Aluminic oxid	9.200	8.760
Manganic oxid (Mn_3O_4)	0.210	0.190
Water at 100° C	2.816	2.111
Ignition	3.918	2.143
Sum	100.281	99.716
Oxygen equivalent to chlorin	0.005	0.007
Total	100.276	99.709

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We will assume that the plants take up all of their nitrogen in the form of nitrates so that the total amount of nitrogen is not so much the question as the rate of nitrification or the rate at which the nitrogen present may become available as plant food. Experiments made with this soil indicate a high power in this direction. The nitric nitrogen was determined at the time of planting and at intervals throughout the season of 1913, i. e., during the growth of the crop. We found at the time of planting very varying results, so much so that any statement relative to the amount of nitrates present not be correct for any other than the particular area taken. With this understanding it may be stated that the approximate amount of nitric nitrogen present at the time of planting was, for the two feet for which the phosphoric acid and potash has been calculated, about 35.16 pounds, corresponding to 211 pounds of sodic nitrate per acre. This amount of nitrogen was at that time available and capable of being appropriated by the young plants.

We used the three conventional solvents in our endeavor to obtain some data pertaining to the availability of the phosphoric acid and potash: hydric chlorid, 1.115 specific gravity; citric acid, 1 percent solution; and one-fifth normal nitric acid. These solvents, in the order given, indicated the presence of the following quantities of these two substances in the first two feet of the soil.

	Potash Pounds	Phosphoric acid—Pounds
Hydrochloric acid	51,520	9,880
Citric acid	1,960	1,440
N-5 Nitric acid	3,080	5,560

These quantities indicate a sufficiency of available plant foods to grow a large number of maximum crops, and explain the fact that the addition of phosphoric acid and potash, even in very liberal quantities, did not produce any observable effects upon the growing plants and only very small effects upon the yield of grain. These are so small that it is only by adhering to a very literal interpretation of the results that we can justify ourselves in claiming any advantage in crop from their use. There is no big, decisive and easily interpreted result produced by their application.

These analytical data are the basis of all of our experiments. They are as satisfactory as any others that we would be likely to obtain, for the mineralogical character of our soil makes it practically impossible to obtain any better or more concordant results, or others which might be more easily interpreted. This soil is exceedingly rich in felspathic sand. The felspar present is for the most part an orthoclase with some microcline. These minerals are readily attacked by decomposing agents, the action of water and carbon dioxide being

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easily demonstrated. Finely powdered felspar will yield potash to growing plants, as I have proved, using the oat plant.

We have not only grown oats in powdered felspar to maturity, with the production of seed, but we have taken our ordinary felspar and treated it just as we do soil samples with citric acid solution and with water to see how much phosphoric acid and potash it will yield to these solvents. Our results indicate that quite as much of these substances may be dissolved out of pure undecomposed felspar as out of our soils by a similar treatment. Felspar crushed to pass through a 60-mesh sieve yielded to a one-percent citric acid solution from 0.015 to 0.030 percent of phosphoric acid and from 0.018 to 0.051 percent of potassic oxid. The action of pure water, distilled water, on pulverized felspar is sufficient to become a factor in our soil problems.

The results in the preceding experiments led us to test the solubility of finely ground apatite in like manner. Apatite ground to pass a 100-mesh sieve yielded to one-percent citric acid 2.25 percent of phosphoric acid and to water 0.042 percent. A blank test made with the citric acid solution showed only an exceedingly minute trace of either phosphoric acid or of potash.

The mineral basis of our soils, according to these results, may play an unusually important part in our questions. Both the coarser and finer portions of this soil are composed largely of particles of felspar in a comparatively fresh condition, but according to the above results, they may serve as a source from which phosphoric acid and potash may be continuously supplied. It will be noticed that the mass analyses of the soil and subsoil give higher results than the analyses with hydric chlorid, specific gravity 1.115. This is probably due to the fact that the coarser portions of the felspar are large enough to protect the apatite contained in them from the action of the acid.

The moisture as well as the nitric nitrogen in the soil varies greatly. Both of these were determined from time to time throughout the season of 1913, and we intended to follow them throughout the season of 1914, but our working force was not large enough to do this and some of the field work done in 1913 could not be done in 1914. I would have preferred to have carried out the same schedule of investigation through the whole period of our field experiments, but we could not and I am not sure that we would have gained anything by doing so; concerning this, however, there may be room for difference of opinion.

NITRIC NITROGEN AND ITS DISTRIBUTION.

The caption states exactly what we intend to present in this section of our work as best we can. While the greater part of the

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samples were taken in the small alleys left between the plots, the results obtained have been checked by samples taken from the ground occupied by the plants. While we realized the objections against taking the samples in this manner, it seemed best to do this, as we desired the crop quite as much as these data. In taking the number of samples that we deemed necessary, the injury to the crop, had they all been taken from the cultivated area, would have destroyed the results.

The width of each section is 132 feet, and no sample was taken within 20 feet of either end. The samples are composite, consisting of three subsamples. The borings were approximately 30 feet apart in a line across the section. These borings were made four feet deep. Other borings, not in the midst of the plants, were made to a depth of twelve feet, unless for some reason we could not accomplish it, which sometimes was the case, due to striking coarse gravel. The selection of the depth of four feet for the shallower borings was determined by the consideration that the wheat roots would probably not go to a materially greater depth. The twelve-foot borings were made to determine that the depth of the water plane was at least this deep, and to learn something of the distribution of the water, also of the nitric nitrogen and its total amount.

The following samples were collected in the spaces between the sections 29 April, 1913; this was three days after the grain was planted. This land is of course always fallow.

MOISTURE AND NITRIC NITROGEN IN SOIL AT TIME OF PLANTING.

Depth	Sample 1		Sample 2	
	Moisture Percent	Nitric Nitrogen Parts per Million	Moisture Percent	Nitric Nitrogen Parts per Million
0 to 6 inches	13.37	10.47	13.00	6.66
7 to 12 inches	17.08	7.75	17.05	5.85
13 to 24 inches	16.20	23.80	16.47	4.22
25 to 36 inches	13.89	33.86	14.65	2.86
37 to 48 inches	12.47	12.92	14.32	5.58
49 to 60 inches	12.69	7.75	16.21	8.57
61 to 72 inches	14.22	5.85	17.96	9.93
73 to 84 inches	15.90	5.58	17.44	11.29
85 to 96 inches	15.57	4.76	17.00	11.02
97 to 108 inches	15.78	4.22	14.87	10.47
109 to 120 inches	16.78	2.58	14.80	7.75
121 to 132 inches	14.00	2.58	15.20	4.22

These two sections of soil were taken less than 150 feet apart, but there is a great variation in the quantities of nitric nitrogen present and its distribution is almost reversed; the maximum quantities being found in the second, third and fourth foot in the first case and in the seventh, eighth and ninth foot in the second case. The supply of nitric nitrogen within reach of any cultivated plant

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was very much greater in the first than in the second sample. While we do not know with certainty, it is very probable that the difference in distribution of the nitric nitrogen is due to a difference in the time of development, the supply of water and the permeability of the soil; the two latter factors facilitating the downward movement of the nitrates.

A second set of three samples was taken in the same manner as those already given on 27 June, twelve to fourteen days after we irrigated the field. The total nitrogen was also determined in this set of samples.

SAMPLE No. 1—27 JUNE, 1913.

Depth.	Moisture Percent	Nitric Nitrogen Parts per Million	Total Nitrogen Percent
0 to 12 inches	16.88	4.49	0.1292
13 to 24 inches	16.70	0.95	0.0653
25 to 36 inches	15.97	0.54	0.0340
37 to 48 inches	18.11	0.54	0.0258
49 to 60 inches	19.87	0.39	0.0177
61 to 72 inches	19.86	0.27	0.0218
73 to 84 inches	18.05	0.68	0.0218
85 to 96 inches	21.40	0.38	0.0218
97 to 108 inches	18.84	0.00	0.0218
109 to 120 inches	18.63	0.00	0.0218
121 to 132 inches	17.96	0.00	0.0218

SAMPLE No. 2.—27 June, 1913.

Depth.	Moisture Percent	Nitric Nitrogen Parts per Million	Total Nitrogen Percent
0 to 12 inches	15.96	2.04	0.1142
13 to 24 inches	16.49	0.95	0.0571
25 to 36 inches	16.41	0.68	0.0313
37 to 48 inches	17.07	0.39	0.0204
49 to 60 inches	18.78	0.39	0.0204
61 to 72 inches	20.15	0.39	0.0204
73 to 84 inches	20.04	0.68	0.0231
85 to 96 inches	20.23	1.22	0.0299
97 to 108 inches	14.78	0.68	0.0177
109 to 120 inches	18.14	0.68	0.0150
121 to 132 inches	19.75	0.68	0.0218

SAMPLE No. 3—27 JUNE, 1913.

Depth.	Moisture Percent	Nitric Nitrogen Parts per Million	Total Nitrogen Percent
0 to 12 inches	14.39	3.13	0.1115
13 to 24 inches	15.54	1.22	0.0530
25 to 36 inches	15.61	0.95	0.0326
37 to 48 inches	16.09	0.68	0.0231
49 to 60 inches	17.60	0.54	0.0204
61 to 72 inches	19.06	0.54	0.0163
73 to 84 inches	18.41	0.39	0.0177
85 to 96 inches	19.23	0.68	0.0258
97 to 108 inches	19.84	0.95	0.0109

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This section was taken to a depth of nine feet because at this point we struck coarse gravel and it was impossible to get the auger any deeper.

We cannot infer that the water applied has washed out an amount of nitrates equivalent to the difference between the amounts shown by the first two and the last three samples, at least I do not consider it safe to make such a supposition, but four-foot samples taken subsequently will make it evident that large amounts of nitrates have actually been washed out of the soil. The amount of water used in this irrigation was one acre-foot, and the condition of the soil was such that this amount of water was necessary to permit the water, with the head that we had, to just flow over the soil. In other words, the ground took in this much water. The extent to which the irrigation had increased the water supply is fairly indicated by the differences in the percentages of moisture on 29 April, when the first samples were taken and those found on 27 June, 12 to 14 days after one acre-foot of water had been applied.

The nitric nitrogen in any foot of the last three samples is comparatively small; even the surface foot contains only a small amount, though it is considerably more than we find in any subsequent foot. There was no nitric nitrogen in the last three feet of the first sample taken on 27 June, though this sample contained the largest amount in the surface foot at that time.

The preceding samples were all taken in fallow strips, for we left spaces between each set of four plots. We did this so that we could take such samples without tramping down an unnecessarily large amount of our wheat. The loss of area due to taking of samples was too large as it was, for we also took samples in the wheat plots proper and cut many samples of plants. We, therefore, have two more series of samples to show the moisture, nitric nitrogen and total nitrogen in the soil throughout the season. These two series were taken to a depth of four feet: one series was taken in the strips left between the plots and the other series in the plots themselves. Each of these series is divided into subseries corresponding with the three sections of land which we used for these field experiments. These sections of land are designated as 1700, 1800 and 1900 and contain about two acres each. There were two sets of samples taken in each section on the dates given. These samples were not taken from one spot, but were composite. Each sample analyzed was composed of three samples which were well mixed before the final sample was taken out. These precautions were necessary in order to obtain a representative sample. I believe that the samples hereafter given are quite representative and de-

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pendable. The first set of nitric-nitrogen determinations was made by the phenolsulphuric acid method, all the others were made by reduction with a zinc-copper couple. With these soils the latter usually gives a shade higher results.

SAMPLES TAKEN 29 APRIL, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	13.60	7.00	14.50	4.00	13.97	4.00
7 to 12 inches....	14.11	6.00	16.91	5.00	17.62	3.00
13 to 24 inches....	15.20	4.50	16.09	3.00	15.78	1.00
25 to 36 inches....	14.69	2.50	14.78	1.50	15.10	1.00
37 to 48 inches....	13.12	2.50	13.52	1.50	13.06	0.15
0 to 6 inches....	14.68	8.00	14.22	8.00	14.58	3.00
7 to 12 inches....	15.79	7.00	17.02	5.00	17.67	4.50
13 to 24 inches....	14.54	4.50	16.52	2.50	16.45	1.50
25 to 36 inches....	14.69	2.50	14.78	1.50	15.10	1.00
37 to 48 inches....	14.81	1.50	14.50	Trace	14.32	0.05

SAMPLES TAKEN 12 MAY, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	16.74	5.58	16.90	11.02	17.18	6.39
7 to 12 inches....	19.18	6.94	18.57	10.20	18.48	6.12
13 to 24 inches....	17.51	2.58	17.08	5.30	15.94	2.04
25 to 36 inches....	15.10	1.22	15.37	2.04	14.59	1.22
37 to 48 inches....	12.93	0.95	14.47	1.22	13.23	0.68
0 to 6 inches....	15.71	6.63	16.36	5.31	16.52	7.21
7 to 12 inches....	19.36	7.48	18.68	10.20	18.53	8.02
13 to 24 inches....	16.90	2.31	16.77	3.67	16.68	2.58
25 to 36 inches....	15.43	0.95	15.12	1.22	15.18	0.68
37 to 48 inches....	14.97	0.68	14.54	0.82	14.63	0.54

From the evening of May 8 to the morning of May 10 we had a rainfall of 1.05 inches.

SAMPLES TAKEN 26 MAY, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	15.37	8.02	15.05	7.62	13.66	6.80
7 to 12 inches....	16.74	9.38	17.83	9.11	16.98	6.66
13 to 24 inches....	15.71	3.67	16.86	3.13	16.19	2.86
25 to 36 inches....	15.02	1.63	15.60	1.90	14.92	0.95
37 to 48 inches....	13.78	0.95	14.14	0.82	14.14	0.54
0 to 6 inches....	15.39	7.21	14.01	6.94	13.42	6.39
7 to 12 inches....	17.74	11.29	17.30	9.38	17.04	5.44
13 to 24 inches....	16.26	3.40	16.16	4.08	16.03	1.63
25 to 36 inches....	15.25	1.63	15.13	2.31	15.26	1.22
37 to 48 inches....	14.72	0.95	15.05	1.77	14.96	0.54

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SAMPLES TAKEN 7 JUNE, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	12.51	8.30	10.77	9.93	11.06	9.66
7 to 12 inches....	16.17	6.94	16.01	9.93	16.08	7.48
13 to 24 inches....	15.36	3.13	15.36	....	15.59	2.86
25 to 36 inches....	14.01	1.22	14.96	1.77	15.25	1.22
37 to 48 inches....	13.96	0.68	14.82	0.95	13.74	0.68
0 to 6 inches....	11.33	7.48	10.36	8.30	10.97	8.30
7 to 12 inches....	16.87	8.84	15.98	9.11	15.81	5.58
13 to 24 inches....	15.99	3.40	15.42	4.49	15.53	1.77
25 to 36 inches....	15.03	1.22	15.28	1.50	14.49	0.95
37 to 48 inches....	15.67	1.22	14.50	0.95	14.52	0.95

We began irrigating five days after the above samples were taken. The water was applied at this time, not because the plants showed any need of it, but because they were for the most part in boot and we deemed this an opportune time to apply it.

SAMPLES TAKEN 24 JUNE, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	11.27	4.49	11.33	7.07	11.84	2.86
7 to 12 inches....	14.44	2.31	15.71	4.90	15.14	1.77
13 to 24 inches....	14.89	0.82	15.08	3.54	15.25	0.68
25 to 36 inches....	15.08	0.00	15.20	2.86	15.57	0.68
37 to 48 inches....	14.92	0.68	15.24	1.16	16.04	0.54
0 to 6 inches....	14.07	7.48	12.90	6.26	12.42	2.72
7 to 12 inches....	16.73	3.67	16.92	4.35	15.49	1.50
13 to 24 inches....	15.90	1.77	16.53	2.18	15.90	0.68
25 to 36 inches....	15.99	1.22	15.59	2.18	16.03	0.68
37 to 48 inches....	17.63	1.50	16.55	1.16	16.92	0.54

SAMPLES TAKEN 14 JULY, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	7.30	6.12	8.16	5.98	8.29	11.15
7 to 12 inches....	13.80	3.13	14.05	3.26	13.71	4.90
13 to 24 inches....	14.17	1.50	14.57	2.72	14.79	....
25 to 36 inches....	15.57	0.95	14.85	2.18	14.87	1.90
37 to 48 inches....	14.06	0.95	14.49	1.16	14.46	1.63
0 to 6 inches....	9.49	8.30	10.87	10.34	7.14	5.44
7 to 12 inches....	15.05	3.67	15.81	8.43	12.69	1.90
13 to 24 inches....	14.87	1.77	15.24	2.18	13.99	1.16
25 to 36 inches....	14.62	1.50	15.46	1.90	11.07	1.16
37 to 48 inches....	15.57	1.22	15.68	1.90	14.80	0.82

The total nitrogen in these sections of land was all redetermined on 1 July, 1913.

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TOTAL NITROGEN IN SAMPLES TAKEN.

Depth.	Section 1700 Total Nitrogen Percent	Section 1800 Total Nitrogen Percent	Section 1900 Total Nitrogen Percent
0 to 6 inches	0.1224	0.1278	0.1238
7 to 12 inches	0.1142	0.1047	0.0843
13 to 24 inches	0.0517	0.0680	0.0558
25 to 36 inches	0.0340	0.0435	0.0394
37 to 48 inches	0.0272	0.0258	0.0258
0 to 6 inches	0.1278	0.1074	0.1278
7 to 12 inches	0.0898	0.0898	0.0952
13 to 24 inches	0.0558	0.0585	0.0517
25 to 36 inches	0.0354	0.0367	0.0367
37 to 48 inches	0.0231	0.0218	0.0231

All of the preceding samples were taken within the fallow strip left between the sets of four plots.

The nitric nitrogen found in the samples taken 7 June, five days before the irrigation, and in those taken 24 June, ten to twelve days after irrigation, gives a measure of the effect of the irrigation upon the nitrates in the soil to the depth to which the samples were taken, four feet. We have six samples, each composed by uniting three subsamples, eighteen subsamples in all, representing six inches or the foot, respectively, given in the tables. We will consider only the surface six inches. The average amount of nitric nitrogen per million for this section of soil before irrigation was 8.66 p.p.m. On 24 June, ten or twelve days after irrigation, it was 5.18 p.p.m., a difference of 3.48 p.p.m. An examination of the tables also shows that these nitrates had been moved either into the lower portion of this section or still deeper. An examination of the next series of samples given, that for 14 July, 1913, gives a very fair idea of the rate at which these nitrates were being replaced, for the surface six inches of these same plots now contains an average of 8.8 p.p.m. a little higher average than was found five days before irrigation. The whole section of soil sampled shows the same fact, but not always to so marked a degree. This accumulation of nitric nitrogen in the surface portions of this soil is not due to immigration of the nitrates from greater depths aided by capillarity. Direct experiment, Colorado Bulletin 186, p. 29, shows that capillary attraction will not move nitrates, under ordinary atmospheric conditions, more than 25 inches in thirty days and their distribution through the soil is the reverse of that which we find in our plots. The increased nitric nitrogen in the soil is due to nitrification. It was shown in Colorado Bulletin 178, p. 86, *et seq.*, also in Colorado Bulletin 179, pp. 14, 26 and 29, by W. G. Sackett, that this soil possesses such high fixing and nitrifying powers that these phenomena are, beyond question, important factors in the production of the nitric nitrogen found.

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The amount of nitric nitrogen found in soil cultivated fallow, compared with the foregoing results on the one hand, and with the nitric nitrogen found in cropped soil on the other hand, is of interest in this connection.

The cropped land referred to in the following tables is the same land for which the nitric nitrogen is subsequently given as sampled 1 August, 1913, Defiance, Check, Section 1700. The wheat was harvested off of the land 6 August. The land was irrigated 28 August and disked a few days later. The land was plowed about 20 October, and the samples were taken 4 December, 1914. These facts are stated in order that the part played by the cultural conditions may be taken into proper consideration.

Six series of samples were taken from the adjoining section of land, three on 14 November and three on 4 December, 1914. This section had been cultivated fallow during the season preparatory for use in wheat breeding experiments. The area of these sections is two acres each.

NITRIC NITROGEN IN FALLOWED LAND.
SAMPLES TAKEN 14 NOVEMBER, 1914.

Depth.	Nitric Nitrogen Parts per Million Sample I.	Sample II.	Sample III.
0 to 3 inches	6.36	8.52	7.37
4 to 7 inches	20.71	28.63	22.03
8 to 13 inches	9.24	18.73	14.74
14 to 19 inches	5.63	3.89	3.88

SAMPLES TAKEN 4 DECEMBER, 1914.

0 to 3 inches	11.12	7.44	14.32
4 to 7 inches	31.13	18.42	25.71
8 to 13 inches	17.11	15.67	18.73
14 to 19 inches	6.57	4.79	6.43

TOTAL NITROGEN IN FALLOWED LAND.
SAMPLES TAKEN 4 DECEMBER, 1914.

Depth.	Percent	Percent	Percent
0 to 3 inches	0.1293	0.1244	0.1230
4 to 7 inches	0.1319	0.1265	0.1225
8 to 13 inches	0.0974	0.1091	0.0987
14 to 19 inches	0.0709	0.0705	0.0677

NITRIC NITROGEN IN LAND CROPPED TO WHEAT.
SAMPLES TAKEN 4 DECEMBER, 1914.

Depth.	Nitric Nitrogen Parts per Million. Sample I	Sample II
0 to 3 inches	6.39	5.42
4 to 7 inches	11.74	7.92
8 to 13 inches	11.82	8.93
14 to 19 inches	6.69	3.44

TOTAL NITROGEN IN LAND CROPPED TO WHEAT.
SAMPLES TAKEN 4 DECEMBER, 1914.

Depth.	Percent	Percent
0 to 3 inches	0.1258	0.1150
4 to 7 inches	0.1223	0.1205
8 to 13 inches	0.1203	0.1101
14 to 19 inches	0.0820	0.0764

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Each of the samples in these series was made up of three sub-samples. The accumulation of nitric nitrogen during the period of fallow is very evident. The facts stated in Colorado Bulletin 205, pp. 36 and 37, regarding the effect of fallowing upon the prevalence of yellow-berry in wheat, taken in connection with the demonstrated effects of nitrates are very suggestive and interesting. The following samples were taken in the same manner as the preceding ones, but in a line running lengthwise through the middle of the plots.

SAMPLES TAKEN WITHIN THE PLOTS 1 JULY, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	14.03	2.72	12.79	2.99	12.51	3.13
7 to 12 inches....	14.36	1.22	14.63	2.58	14.49	1.90
13 to 24 inches....	14.95	0.68	15.16	0.68	15.22	0.54
25 to 36 inches....	14.95	0.39	15.29	0.39	16.07	0.27
37 to 48 inches....	15.67	0.27	15.84	0.27	15.75	0.27
0 to 6 inches....	12.57	4.76	12.24	....	15.06	3.40
7 to 12 inches....	14.43	2.04	14.34	2.18	16.47	1.22
13 to 24 inches....	14.39	0.95	14.63	1.16	15.76	0.68
25 to 36 inches....	14.87	0.95	14.75	1.09	15.85	0.54
37 to 48 inches....	17.77	0.68	16.27	....	16.33	0.54

SAMPLES TAKEN WITHIN THE PLOTS 14 JULY, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	9.16	1.02	9.51	3.26	8.30	2.72
7 to 12 inches....	10.47	0.00	10.69	1.09	9.75	1.09
13 to 24 inches....	11.62	0.00	10.38	1.09	10.17	1.16
25 to 36 inches....	12.76	0.00	11.72	1.09	10.92	1.63
37 to 48 inches....	13.31	0.00	13.05	0.82	12.22	0.82
0 to 6 inches....	7.99	2.31	8.73	3.94	8.83	3.54
7 to 12 inches....	9.66	1.02	10.28	1.63	10.26	3.81
13 to 24 inches....	10.20	1.09	9.90	1.63	9.70	1.16
25 to 36 inches....	11.93	0.95	11.88	1.09	11.18	1.09
37 to 48 inches....	14.22	0.54	13.10	0.39	13.37	0.68

SAMPLES TAKEN WITHIN THE PLOTS 1 AUGUST, 1913.

Depth	Section 1700 Moisture Percent	Section 1700 Nitric Nitrogen Parts per Million	Section 1800 Moisture Percent	Section 1800 Nitric Nitrogen Parts per Million	Section 1900 Moisture Percent	Section 1900 Nitric Nitrogen Parts per Million
0 to 6 inches....	13.76	4.35	14.07	2.99	14.59	2.99
7 to 12 inches....	14.40	2.99	16.07	2.99	16.14	2.18
13 to 24 inches....	11.23	1.09	16.02	0.95	16.28	0.82
25 to 36 inches....	12.46	0.82	15.98	0.54	16.33	0.82
37 to 48 inches....	12.50	0.54	16.15	0.27	15.52	0.27
0 to 6 inches....	13.76	4.49	12.82	5.17	13.51	2.45
7 to 12 inches....	14.59	3.26	16.16	2.72	16.86	1.63
13 to 24 inches....	11.90	1.16	16.83	1.09	16.20	0.54
25 to 36 inches....	11.06	1.09	16.13	0.82	15.70	0.27
37 to 48 inches....	13.14	0.54	16.04	0.54	16.53	0.54

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The land was not well leveled before planting and when we came to irrigate it there were a few spots on which it was impossible to force the water. These spots were comparatively small and I thought that the lateral movement of the water beneath the surface would effect a subirrigation, but in this I was wrong. The wheat on these spots matured as good wheat as the irrigated portion but the growth of the straw was very inferior to the rest of the plots in which they occurred. Because of the evident deficiency of water as indicated by the growth and color of the plants, I took a set of samples from one of these spots on 2 August, just a few days before harvest, and had the moisture and nitric nitrogen determined in them. The spot chosen was in Section 1700, Fife-Check plot. I have just given, in the last table, the moisture and nitric nitrogen for the regular samples taken the previous day, 1 August.

SAMPLE FROM UNIRRIGATED SPOT TAKEN 2 AUGUST, 1913.

Depth.	Section 1700 Moisture Percent	Nitric Nitrogen Parts per million
0 to 6 inches	12.17	8.70
7 to 12 inches	12.00	8.43
13 to 24 inches	8.56	2.99
25 to 36 inches	7.78	2.18
37 to 48 inches	11.32	1.09

It will be noticed that all of the samples taken 1 August were higher in moisture than those taken 14 July. This is not only true of all the shallower samples, but also of all of the samples; even in the fourth foot the moisture shows a very decided increase. I know of no cause for this except it be found in the fact that between 22 and 27 July we had a total rainfall of one and forty-three hundredths inches. Assuming that we had a rainfall of one and one-half inches, it would give us about 341,000 pounds of water per acre, provided it had all reached the ground, been absorbed and none had been evaporated, all of which is more or less contrary to the facts, for it did not all reach the ground, but lodged on the plants and was evaporated from their surfaces and some of that which did reach the ground had been lost by evaporation or by the activity of the plants and yet on 1 August there is an excess of moisture in the soil taken to a depth of four feet, over that present on 14 July, by over twice the amount that had fallen as rain and we are neglecting the activity of the plants for the whole of the intervening period. This slight rainfall is undoubtedly the cause of the moisture in the first foot of the unirrigated spot.

The nitric nitrogen is also very much higher in this dry spot than in the regular samples, almost as high at the surface as the fallow ground, and decidedly higher in the lower portions of the boring. This may be due to the fact that the wheat plants were

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not very vigorous and did not occupy the ground with their roots, a fact which may have favored nitrification. There was certainly no nitrates washed out of any portion of this soil by irrigating water; on the other hand the lateral movement of the irrigating water does not seem to have been sufficient to account for any accumulation by lateral secretion. If this actually took place to any extent at all, it would have been at the margins of the space, which we avoided, and took the sample as near the center of the dry area as possible.

MOISTURE AND TOTAL NITROGEN IN SAMPLES TAKEN WITHIN THE PLOTS 1 JULY, 1913.

Depth	Section 1700		Section 1800		Section 1900	
	Moisture Percent	Total Nitrogen Percent	Moisture Percent	Total Nitrogen Percent	Moisture Percent	Total Nitrogen Percent
0 to 6 inches	14.03	0.1278	12.79	0.1115	12.51	0.1251
7 to 12 inches	14.36	0.1156	14.63	0.1115	14.49	0.1088
13 to 24 inches	14.95	0.0721	15.16	0.0626	15.22	0.0490
25 to 36 inches	14.95	0.0340	15.29	0.0313	16.07	0.0231
37 to 48 inches	15.67	0.0258	15.84	0.0286	15.75	0.0161
0 to 6 inches	12.57	0.1292	12.24	0.1265	15.06	0.1251
7 to 12 inches	14.43	0.1047	14.34	0.1006	16.47	0.1006
13 to 24 inches	14.39	0.0598	14.63	0.0598	15.76	0.0544
25 to 36 inches	14.87	0.0313	14.75	0.0380	15.85	0.0218
37 to 48 inches	17.77	0.0286	16.27	0.0286	16.33	0.0190

If we consider the water contained in the soil on 29 April and 27 June, about fourteen days after irrigation, we observe that the irrigated land contains the greater percentages of moisture at all depths down to the twelfth foot. These percentages are comparable as both sets of samples were taken from fallow ground. But if we can compare the amounts of nitric nitrogen present, we observe great irregularities in distribution and scarcely any comparison at all in the quantities present. There is one thing very apparent and that is the extent to which the application of one acre-foot of water has removed the nitrates. The moisture present in the April samples was due to a series of light rains insufficient to effect leaching of the ground, whereas an acre-foot of water applied under our conditions affected a very perceptible amount of leaching. I do not know the rate of percolation, but when this amount of water is applied, the surface portions of our soil become very soft, so soft that one will sink into it half-leg deep. There is no doubt but this mass of water passes downward rapidly, as the amount present exceeds the capacity of the soil that it successively occupies to retain it. We can compare the results in another way; we can compare the percentages of water found for the four-foot samples taken 7 June, five days before irrigation, and the top four feet of the samples taken 27 June, about fourteen days after the irrigating had been

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finished. The differences are much smaller than we would expect and will aggregate approximately one percent in favor of the samples taken after irrigation. Some of the water had been removed by evaporation, but the greater portion of it sank rapidly to such a depth that evaporation took place slowly and from the ground surface only. An acre-foot of water is sufficient to increase the moisture in eleven acre-feet of soil by about six and one-quarter percent. We have no such increase. In the fourteen days elapsing since its application it has either evaporated from the surface or percolated through the soil to a greater depth than eleven feet, and this water moving through the soil has taken with it the greater part of the nitrates. In the samples taken 29 April, we find in the third foot 33.86 parts per million, and in the same foot of another sample taken at the same time we find 2.86 parts per million, but in the seventh, eighth and ninth foot we find this reversed, the smaller quantities being in the first sample. The nitrates have been washed further down in the latter than in the former sample.

The effect of the crop upon both the moisture and nitric nitrogen in the soil is evident from the samples taken 14 July, within the plots and in the spaces between the plots. Evidently the shading of the ground causes the top six inches to show a slight excess over the surface of the unprotected ground, but the next six inches and the remaining three feet show differences in moisture up to five percent or rather more. The samples taken within the plots are low in nitric nitrogen, the maximum being 3.94 parts per million, while the corresponding sample from the space between the plots contained 10.34 parts per million. In regard to the lower water content of the soil within the plot, no one will question its being due to the action of the plants and the difference represents principally the water taken up by the plants and given up to the air. Concerning the nitric nitrogen, two things may have happened. The occupancy of the ground by the plants may have prevented the formation of the nitrates and there may never have been as large a quantity in the soil within the wheat plots as in the unoccupied space between the plots, or the plants may have used up the difference that we find between the nitric nitrogen content of the samples. We are sure that the latter process took place, but we do not know certainly that the former supposition is not true. It is maintained that it is true.

The differences in the total nitrogen present in the soil within the plots and in the spaces between the plots are so small, that we are inclined to attach no value to them, especially when we remember that it is exceedingly difficult to select two samples of soil that are really comparable in this respect, and the difficulty of making chemical determinations which are free from all errors. Very slight

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differences in percentages often have a significance, but our methods and operations are not so perfect that we are justified in attaching too much significance to differences that are, perhaps, no greater than our errors. The total nitrogen does not show sufficient differences to justify us in attaching much importance to them, but the percentages of moisture and the quantities of nitric nitrogen do justify such inferences as have been presented.

The question of how great variations may be found in a series of samples taken at very small distances apart has been considered. To put the question to a practical test, we selected an apparently uniform plot, 5 feet by 30 feet, and laid it off in 150 equal squares and took a sample to a depth of one foot from the center of each square. We have six blocks, each five feet square, which gives us twenty-five samples in a block. The total and nitric nitrogen was determined in each of these samples, which were taken 19 May, 1913. The results are shown in the table on the next page.

The smallest amount of total nitrogen found was 0.11016 percent, Sample 8, Block 6. One sample in Block 1 and two samples in Block 4 also contained this amount. The largest amount found was 0.14552 percent. This was in sample 13, Block 6, so that we have the minimum and maximum in adjacent areas one foot square. This difference amounts to 354.4 parts of nitrogen per million. The significance of this amount of nitrogen at a given time will depend upon the character of the compounds of which it forms a part. The amount of organic matter that it represents may be readily seen from the following: Nitrogen forms approximately one-sixth of proteid matter and an acre-foot of soil weighs about four million pounds. These factors give us for the nitrogenous organic matter corresponding to the difference found for the total nitrogen in these samples, four and one-quarter tons, or the equivalent of about seven tons of dried blood of average grade.

The difference for the average of the nitric nitrogen in twenty-four samples from Block 1, and twenty-five samples in Block 6, is 1.8 p.p.m. This may seem a small difference, but it is actually a larger amount than we sometimes find in cropped soils taken to the same depth.

The maximum variation in the nitric nitrogen found within this area, five feet by thirty feet, is from 5.44 to 14.18 p.p.m., a difference of 8.6 p.p.m., or a difference equivalent to 206 pounds of sodic nitrate per acre-foot of soil.

We also determined the variation in the amounts of phosphoric acid and potash within this area; but we reduced the number of samples to four from each five-foot square. The choice was arbitrary, but the same for each of the six blocks, in which the first,

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VARIATION OF TOTAL AND NITRIC NITROGEN IN 150 SQUARE FEET OF SOIL.

Sample Number	Block 1		Block 2		Block 3		Block 4		Block 5		Block 6	
	Total Nitrogen Percent	Nitric Nitrogen p.p.m.	Total Nitrogen Percent	Nitric Nitrogen p.p.m.	Total Nitrogen Percent	Nitric Nitrogen p.p.m.	Total Nitrogen Percent	Nitric Nitrogen p.p.m.	Total Nitrogen Percent	Nitric Nitrogen p.p.m.	Total Nitrogen Percent	Nitric Nitrogen p.p.m.
1.....	0.13056	7.34	0.12648	6.32	0.13056	9.35	0.11560	7.97	0.13464	11.27	0.12920	11.66
2.....	0.11968	6.12	0.14144	9.18	0.13736	.....	0.11152	6.02	0.13328	9.86	0.13464	9.35
3.....	0.11560	6.12	0.13056	6.99	0.12104	8.14	0.12920	7.14	0.13328	12.63	0.12376	7.82
4.....	0.11696	6.97	0.12784	.....	0.12512	7.97	0.13464	8.35	0.13464	.....	0.12104	7.99
5.....	0.13192	5.44	0.11968	6.02	0.12920	8.35	0.13464	7.38	0.11424	7.58	0.12376	9.69
6.....	0.11832	8.33	0.12104	11.08	0.11560	8.55	0.13056	7.99	0.11560	7.32	0.13056	11.07
7.....	0.11968	9.01	0.12240	11.08	0.11016	7.65	0.12240	10.88	0.13056	12.24	0.12920	7.97
8.....	0.11832	9.33	0.11288	7.77	0.12104	9.33	0.12240	9.32	0.13736	10.20	0.11016	8.16
9.....	0.13328	11.73	0.11832	9.13	0.13328	11.66	0.12920	8.16	0.13192	10.10	0.11016	7.97
10.....	0.12104	9.69	0.12104	7.97	0.12376	9.29	0.12512	7.99	0.11152	7.97	0.13328	9.52
11.....	0.12784	9.69	0.12648	6.41	0.13056	9.91	0.11152	8.16	0.12648	8.33	0.13464	10.10
12.....	0.11016	6.41	0.11696	7.58	0.12784	8.84	0.11968	9.52	0.13600	10.88	0.13600	8.33
13.....	0.11560	7.97	0.12784	7.65	0.12104	8.74	0.13056	11.56	0.12648	9.52	0.14552	14.18
14.....	0.12784	8.35	0.13192	9.52	0.12512	9.32	0.13056	8.84	0.12920	7.93	0.14416	10.69
15.....	0.13056	.....	0.12684	8.35	0.11968	7.97	0.11560	8.16	0.12376	9.29	0.12784	7.97
16.....	0.12240	10.20	0.14280	9.01	0.11288	8.94	0.12784	8.43	0.11696	7.31	0.12512	12.41
17.....	0.11832	10.20	0.12104	10.61	0.12648	8.55	0.12648	8.61	0.13872	8.94	0.13056	10.30
18.....	0.12376	10.71	0.13056	9.52	0.12104	10.30	0.14008	9.18	0.13192	8.35	0.13056	12.41
19.....	0.12512	8.67	0.12784	9.29	0.11696	7.97	0.13056	8.43	0.13464	10.30	0.11696	11.05
20.....	0.13328	9.35	0.11696	9.69	0.13736	10.54	0.12648	10.30	0.12512	8.55	0.12784	9.29
21.....	0.13600	11.46	0.12104	8.55	0.13192	13.41	0.13056	7.97	0.12104	9.52	0.13872	12.24
22.....	0.12240	7.97	0.11696	7.65	0.12512	8.74	0.13192	9.13	0.13056	11.46	0.13600	10.30
23.....	0.11696	7.97	0.12920	11.39	0.13736	.....	0.13328	7.97	0.13464	9.71	0.14144	9.52
24.....	0.12376	10.03	0.12648	9.52	0.13056	9.91	0.12240	9.35	0.13464	9.18	0.13600	12.07
25.....	0.13872	8.74	0.12784	9.33	0.13464	8.35	0.13056	11.73	0.12512	7.99	0.12784	9.52

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eighth, eighteenth and twenty-fifth were chosen. The method of extraction was with hydric chlorid, specific gravity 1.115, for ten hours. Two samples out of each four were treated a second time, namely, samples 8 and 18 of each block. The second extraction takes up a further quantity of each of these substances, but particularly of the potash. We were aware of this fact before we made these analyses. The new portion of potash unquestionably comes from the progressive decomposition of the felspar. This fact puts every potash determination made in our soils by this method in more or less doubt. I do not believe, however, that it is a serious matter, for the amount of potash involved is so large that a considerable mistake will matter but little, besides, even fresh felspar yields potash to plants or even to water, so that a mistake of 10 to 15 percent of the total potash involved does not in this case seem to me a very serious matter. For the sake of clearness and brevity, I shall give only the twelve results obtained by the double extraction as sufficient to show the variation in the amounts of phosphoric acid and potash within small, consecutive areas to a depth of one foot. It has already been explained that each block is five feet square and contains twenty-five square feet, which are numbered from left to right, beginning at the upper left-hand corner.

VARIATION OF PHOSPHORIC ACID AND POTASH IN CONSECUTIVE AREAS

Block	Sample	Phosphoric Acid Percent	Potash Percent
1	8	0.140	0.775
1	18	0.140	0.736
2	8	0.143	0.745
2	18	0.143	0.785
3	8	0.132	0.751
3	18	0.157	0.713
4	8	0.134	0.722
4	18	0.145	0.787
5	8	0.147	0.743
5	18	0.145	0.745
6	8	0.131	0.698
6	18	0.153	0.739

The variation in these results for the phosphoric acid extracted from the soil by this method is 0.026 percent, and for the potash 0.089 percent. The absolute amounts of phosphoric acid and potash indicated by these percentages are sufficient to have, possibly, some influence, but we can scarcely think that we are justified in laying any stress upon them, because we know that their common source is the felspar and we cannot regulate the extent to which the solvent shall act upon it in a given time. The quantities actually involved are, for the phosphoric acid, 1040 and, for the potash, 3560 pounds for the acre-foot of soil sampled; whereas the total quantities soluble in the solvent used, are about 5600 pounds for the phosphoric

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acid and 30,000 pounds for the potash. With such quantities present the variations shown by our analytical results, even if these be absolutely correct, are too uncertain in their significance to justify us in seriously undertaking to interpret them. These samples show so little variation, even though quantities greatly in excess of those available to the plants may be involved, that there can be but little object in considering them further. Reference to the analyses of this soil given on a preceding page (11) will further justify us in assuming that, while there may be some variation in the supply of phosphoric acid and potash in small and adjacent pieces of this land, the range is too small to admit of definite assertions in regard to its effects, especially as our knowledge of results obtained with the application of these individual fertilizers to this land leads us to believe that there is an abundant available supply of them present. This is the testimony of the crops raised and not simply an opinion.

We have presented the last few paragraphs to exhibit, as far as we can depend upon our data, the variation in the amounts of nitrogen, nitric nitrogen, phosphoric acid and potash from foot to foot within a small area. We could not, because of lack of time, examine plants, especially the wheat grown on a similar plot, to learn whether the composition of the wheat varied in a corresponding manner. We find, however, in Bulletin No. 269 of the Bureau of Plant Industry, that Prof. E. G. Montgomery, in trying to determine the "Experimental Error in the Nursery and Variation in Nitrogen and Yield," has practicaly done this and finds, using the nitrogen content as his measure, that there is a decided variation from place to place within very small areas. Prof. Montgomery determined this difference in quadrangular areas and also in parallel rows. He adopted as his standards of classification all plants yielding grain below 2.2 percent—from 2.2 to 2.8; from 2.8 to 3; and all plants above 3 per cent. While these standards seem high they served his purpose well. The general result obtained was that the "highs" and "lows" tend to segregate, that is, there would be an area in which they would obtain, as a rule, high results, again an area in which they obtained low results. Concerning these variations he says: "Just why these wide fluctuations occur when every precaution is taken to grow plants under uniform conditions is not very apparent." Again he says: "It is difficult to explain why such great variations exist when there seems to be little or no tendency to transmit them. It seems apparent that the variations must be due to differences in environment. Since the ordinary factors of environment, as sunlight, warmth, moisture and apparent fertility of the soil, are constant for all plants under our nursery conditions, we must conclude that

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there are factors profoundly influencing the growth of plants beyond the ordinary range of observation." Later Professor Montgomery adds, "A number of interesting problems are suggested. Why should one plant, growing under practically the same environment as another, collect from the soil two or three times as much nitrogen." Again, "The three plants * * * are from the same mother growing in the same centgener, probably less than two feet apart, yet the actual grams of nitrogen gathered differ more than 100 percent. This difference is not inherited, as these plants rarely transmit this quality." Professor Montgomery does not ascribe this difference to the soil, and the quotations are not made for the purpose of intimating that he does, but simply to show that variations in the composition of individual plants, growing, as is here asserted, within two feet of one another, may be very great, and that the difference in their nitrogen content cannot be attributed to heredity. The inference that I draw from the facts given is that there was a relation between the soil and these variations, but we shall find occasion to come back to this subject at another time.

SOME SURFACE SAMPLES OF SOIL AND THEIR BACTERIAL CONTENT.

It was proposed to study the relation between the moisture, the number of bacteria, the total nitrogen and the nitric nitrogen present from time to time. Our plan proved to be more generous in scope than our ability to perform. In addition to this Professor Sackett did not encourage me with the promise of any easily interpreted results, as the bacterial counts do not include all of the bacteria, one or more important classes being eliminated by the character of the culture medium used.

In this connection it may be well to note one of the effects of turning the land to such a depth as I did, twelve inches in two cases and nine inches in one case, whereby I put several inches of the subsoil on the surface, at least two inches by the shallower and five or six inches by the deeper plowing. This plowing was done in the spring immediately before seeding. I appreciated the disadvantages of the procedure, but as previously explained, I had, owing to circumstances over which I had no control, no choice if I wished to give the land a deep plowing. The result was that the surface of my plots represented unweathered subsoil with a comparatively meager bacterial population. We united twenty samples of this subsoil to form a composite one taking care that the samples should not be inoculated by admixture of surface soil or by other means. Professor Sackett kindly made the bacterial count which he reported to us as—bacteria 911,875, moulds 97,975 per gram

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of soil. These samples represented six inches of this subsoil. Later we took a few samples from different sections to the depth of three inches and determined the moisture, the total nitrogen and the nitric nitrogen and Professor Sackett made bacterial counts in a few of them. Whether the depth of three inches was well chosen is a question, but this would depend largely upon the immediately preceding weather conditions. The samples were all taken on the same date and we considered them comparable. The results were as follows:

MOISTURE, BACTERIA, ETC., IN SURFACE THREE INCHES OF SOIL.

Section	Moisture Percent	Total Nitrogen Percent	Nitric Nitrogen Parts per Million	Bacterial Count
Corn	7.880	0.12444	9.11	
Corn	8.859	0.12988	7.48	
Corn	7.102	0.12716	10.47	
Sorghum	7.206	0.12444	6.55	
Winter wheat	4.986	0.11968	2.58	
Winter rye	4.180	0.12172	2.72	834,000
Spring wheat check	4.825	0.13328	3.81	1,440,000
Spring wheat P_2O_5 applied	6.510	0.14552	3.67	2,483,000
Spring wheat KCl applied	5.614	0.13872	5.71	
Soil taken eight inches deep				1,560,000
Subsoil 9 to 14 inches				476,000

These samples were taken 20 June, a time when 4,000,000 bacteria per gram may be taken as a fair average for an ordinary loamy soil. These soils are very much poorer in bacterial life than the average; this is true even in the case of the plot to which we had added phosphoric acid which seems to have favored their development very greatly. The subsoil is very much poorer than the entire sample given above—in fact, it contains practically only one-half as many bacteria which developed on the culture medium employed. It will be noticed that the soils of our spring wheat plots, while richer in total nitrogen, were decidedly poorer in nitric nitrogen than the corn and sorghum plots.

We have not been able, up to this time, to pursue the study of the relation between the moisture, crop, nitrogen supply, etc., to any greater extent than is indicated by the statements given, which are not sufficient to justify any conclusions but they suffice for the purpose for which they are introduced, which is to show that the turning of five or six inches of subsoil to the surface and planting in this immediately after turning, gave us, in all respects, unusual conditions for which, if we only knew how, allowances should be made.

This subject is not permanently dismissed for I am satisfied that this is one of the most important factors in our problem, and if strength and opportunity be granted me, I shall prosecute it

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further, for herein lies, I am fully persuaded, the explanation for the variations in the total, as well as in the nitric nitrogen present in the soil from foot to foot, and also one of the causes of variation in the composition and quality of the wheat produced.

These statements are made with a full knowledge and appreciation of the important influence attributed to "climatic conditions." While there can be no question about the importance of the factors, designated by this term, uniformity of climatic conditions does not mean uniformity in characteristic properties of the same variety of wheat. On the contrary, given uniformity of climatic conditions, we can influence both the physical properties and chemical composition of the wheat kernel by varying the relative amounts of the individual substances necessary for plant growth. We can, by supplying nitrogen, cause the kernel to be small, maybe shrunken, flinty, high in nitrogen and difficult to crush; or by increasing the potassium in the soil, we can cause it to be large, plump, high in starch, correspondingly low in nitrogen and easy to crush. These properties constitute those groups which, so far as I can gather, are characteristic of the two classes of wheat usually designated as "hard" and "soft" wheats. In making these statements at this time I disclaim the expression of any opinion concerning strong and weak flours; this is a matter for future consideration.

NITROGENOUS COMPOUNDS IN THE DEVELOPING PLANTS.

In our study of the sugar beet* we found it comparatively easy to follow the development and disappearance of the various forms of nitrogen in the blades of the leaves, the petioles and in the root. We made the attempt to follow the development of the nitrogenous compounds in the wheat plant from the time of blooming till the plant was mature. The same methods were used in this as in the former case except that we made no attempt to determine the animo-group and we used only the stems, leaves and heads of the plants. The sheaths for the most part were taken with the stems. The plants came into bloom about 7 July, a few anthers appeared 6 July and they had practically all disappeared by 10 July, so I take it that the period of full bloom was from 6 to 8 July.

RATIOS OF LEAVES, STEMS AND HEADS.

The effects of the individual fertilizers applied to the different plots were not discernible in the growth or color of the various plots of wheat except in the case of those to which sodic nitrate had been applied. These plots were decidedly greener, leafier and a little taller than the others. We could not detect any difference between the other plots. We took three sets of samples from two

*Bulletin 183, Colo. Exp. Sta.

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sections and two sets from the third section in order to determine the green weight of the stems, leaves and heads. We confined these observations to the Red Fife. We chose the Fife because we judged it to be more nearly representative than the other varieties and because it was somewhat more advanced in development. The portion designated as leaves was obtained by stripping the stems by drawing them through the hand. In this manner we got the blade and part of the sheath, but this portion consisted mostly of blades. The first samples were taken 7 July, 1913, and the latest samples 5 August, but the wheat was so nearly ripe on this last date that the leaves formed only about 4.0 percent of the plant and are included with the stems. The percentages given in the following tables are for green weights.

RATIO OF STEMS, LEAVES AND HEADS FOR RED FIFE.

Date	Fertilizer per acre	Stems Percent	Leaves Percent	Heads Percent
Sections 1700				
7 July, 1913	Nitrogen, 120 pounds	65.40	18.47	16.13
	Phosphorus, 60 pounds	66.57	14.26	19.17
	Potassium, 200 pounds	65.24	12.99	21.77
	None	70.84	14.58	14.58
21 July, 1913	Nitrogen, 120 pounds	56.64	12.65	30.71
	Phosphorus, 60 pounds	54.48	8.50	37.02
	Potassium, 200 pounds	54.73	9.40	36.47
	None	54.60	9.91	35.48
4 August, 1913	Nitrogen, 120 pounds	56.27	.....	43.73
	Phosphorus, 60 pounds	54.00	.....	46.00
	Potassium, 200 pounds	57.35	.....	42.65
	None	53.80	.....	46.20
Section 1800				
7 July, 1913	Nitrogen, 80 pounds	60.22	15.59	24.19
	Phosphorus, 40 pounds	69.05	13.49	17.46
	Potassium, 150 pounds	66.60	14.99	18.41
	None	69.39	13.49	17.21
25 July, 1913	Nitrogen, 80 pounds	59.88	8.56	31.56
	Phosphorus, 40 pounds	56.25	7.23	36.52
	Potassium, 150 pounds	54.66	6.43	38.91
	None	55.92	9.86	34.22
5 August, 1913	Nitrogen, 80 pounds	58.76	.....	41.24
	Phosphorus, 40 pounds	57.41	.....	42.59
	Potassium, 150 pounds	58.67	.....	41.33
	None	56.97	.....	43.03
Section 1900				
13 July, 1913	Nitrogen, 40 pounds	63.01	12.52	24.47
	Phosphorus, 20 pounds	62.07	10.09	27.84
	Potassium, 100 pounds	61.57	10.13	28.30
	None	62.77	9.70	27.53
30 July, 1913	Nitrogen, 40 pounds	56.70	7.10	31.16
	Phosphorus, 20 pounds	55.68	6.64	37.68
	Potassium, 100 pounds	53.47	5.15	41.38
	None	54.74	7.05	38.21

We could only make an approximate determination of the total green matter per acre by cutting the plants on a given small area and weighing the same. We did this as accurately as we could and

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obtained the following figures on 15 July, 1913, for Section 1700: Nitrogen applied, 120 pounds per acre, 10.1 tons; phosphorus applied, 60 pounds per acre, 8.3 tons; potassium applied, 200 pounds per acre, 7.4 tons; check, which received no fertilizer, 7.0 tons. The tables given above, together with these approximate figures, serve to give an idea of the effects produced upon the production of green matter by the fertilizers applied and some idea of the relative development of stems and heads.

THE DRY MATTER IN THE PLANTS.

The dry matter in the plants was also determined, but we had to use other samples. The earliest sample taken for this purpose was cut 7 July, 1913, at the time of blooming. The results are given in the following table for the whole plant till 28 July, but on this and subsequent dates the stems and heads were weighed separately.

DRY MATTER IN WHEAT PLANTS GROWN WITH DIFFERENT FERTILIZERS.

Date	Section	Variety	Fertilizer per acre	Air-dry matter Percent
7 July, 1913	1700	Defiance	120 pounds nitrogen	27.02
7 July, 1913	1700	Defiance	60 pounds phosphorus	30.78
7 July, 1913	1700	Defiance	200 pounds potassium	31.71
7 July, 1913	1700	Defiance	None	30.00
9 July, 1913	1700	Red Fife	120 pounds nitrogen	29.47
9 July, 1913	1700	Red Fife	60 pounds phosphorus	34.22
9 July, 1913	1700	Red Fife	200 pounds potassium	34.06
9 July, 1913	1700	Red Fife	None	34.29
9 July, 1913	1700	Kubanka	120 pounds nitrogen	32.66
9 July, 1913	1700	Kubanka	60 pounds phosphorus	33.60
9 July, 1913	1700	Kubanka	200 pounds potassium	32.42
9 July, 1913	1700	Kubanka	None	32.66
10 July, 1913	1900	Defiance	40 pounds nitrogen	29.38
10 July, 1913	1900	Defiance	20 pounds phosphorus	33.60
10 July, 1913	1900	Defiance	100 pounds potassium	32.34
10 July, 1913	1900	Defiance	None	32.34
10 July, 1913	1900	Red Fife	40 pounds nitrogen	30.55
10 July, 1913	1900	Red Fife	20 pounds phosphorus	36.25
10 July, 1913	1900	Red Fife	100 pounds potassium	33.83
10 July, 1913	1900	Red Fife	None	33.75
10 July, 1913	1900	Kubanka	40 pounds nitrogen	31.34
10 July, 1913	1900	Kubanka	20 pounds phosphorus	32.11
10 July, 1913	1900	Kubanka	100 pounds potassium	33.05
10 July, 1913	1900	Kubanka	None	30.86

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DRY MATTER IN WHEAT PLANTS, STEMS AND HEADS SEPARATE.

Date 1913	Section	Variety	Fertilizer per acre	Dry matter stems	Dry matter heads	Ratio of green stems to heads
28 July	1700	Defiance	120 pounds nitrogen	42.30	46.54	1.5
28 July	1700	Defiance	60 pounds phosphorus	48.03	52.30	1.2
28 July	1700	Defiance	200 pounds potassium	45.97	49.80	1.3
28 July	1700	Defiance	None	43.65	48.40	1.3
31 July	1700	Red Fife	120 pounds nitrogen	44.77	54.74	1.3
31 July	1700	Red Fife	60 pounds phosphorus	49.98	56.80	1.2
31 July	1700	Red Fife	200 pounds potassium	43.84	60.06	1.2
31 July	1700	Red Fife	None	45.45	55.88	1.3
29 July	1800	Defiance	80 pounds nitrogen	42.05	44.87	1.9
29 July	1800	Defiance	40 pounds phosphorus	53.97	52.52	1.3
29 July	1800	Defiance	150 pounds potassium	47.40	49.11	1.5
29 July	1800	Defiance	None	43.89	47.78	1.5
29 July	1800	Kubanka	80 pounds nitrogen	51.81	53.37	1.3
29 July	1800	Kubanka	40 pounds phosphorus	47.28	54.80	1.2
29 July	1800	Kubanka	150 pounds potassium	57.96	56.77	1.3
29 July	1800	Kubanka	None	51.69	58.12	1.3
30 July	1900	Defiance	40 pounds nitrogen	49.45	47.42	1.7
30 July	1900	Defiance	20 pounds phosphorus	53.53	50.83	1.3
30 July	1900	Defiance	100 pounds potassium	47.26	47.92	1.4
30 July	1900	Defiance	None	51.93	49.58	1.3
30 July	1900	Red Fife	40 pounds nitrogen	51.99	54.52	1.8
30 July	1900	Red Fife	20 pounds phosphorus	51.76	54.80	1.6
30 July	1900	Red Fife	100 pounds potassium	48.23	56.90	
30 July	1900	Red Fife	None	49.47	55.51	

There is no question but that the tendency of the nitrate is to lessen the percentage of dry-matter in the plant. This is quite evident in the earlier samples and it is still true in the later ones though less pronounced and regular.

The samples of Defiance given in this table all seem to be remarkably low in dry matter. These are, however, the results obtained and I have no explanation to offer unless it be due to immaturity of the variety which requires about ten days longer for its normal development than the Red Fife. The preceding samples were dried in a large steam drier and then permitted to stand exposed to the atmosphere till they had absorbed as much moisture as they would under our atmospheric conditions before being weighed.

A few samples taken at random were used to ascertain how much moisture such samples contained. The average for seven samples used was 7.482 percent (Max. 8.652, Min. 5.566 percent). The samples grown with the application of nitrate contained higher percentages of moisture than the others, but the few samples tested do not justify the extension of this observation to all samples as a general rule.

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THE EFFECTS OF FERTILIZERS AS INDICATED BY THE NITROGEN CONTENT OF THE PLANT.

The data previously given lead to the questions suggested by this caption. The most important questions that present themselves in our work during a given year pertain to the part played in the nutrition and development of the plant by the inorganic constituents available in the soil. Perhaps we should consider the absolute supply and the ratio of the respective substances.

The climatic influences for any given year are eliminated by the fact that they are the same for all series of experiments made during that year and our varying results in the different individual experiments cannot be attributed to the differences in this respect. All will agree that nitrogen is the inorganic constituent of the soil most easily traced during the development of the plant and at the same time the most important one both directly as a plant food and indirectly by its influence upon the appropriation of other ash constituents, and also upon the subsequent processes within the plant, depending upon the relative quantities of these present. In order to follow these processes we adopted the nitrogen content and its various forms, the amino group excepted, as the criteria whereby to judge of the influence of the nitrogen applied in the soil. It is our intention to try to follow these throughout the development of the plant from the time of bloom till the wheat is ripe and even into the flour. In order to accomplish this purpose we shall give the total nitrogen, the proteid nitrogen, the nitrogen present as ammonia and as amid.

We omit the amino-group in our analysis of the plant because we judge it, from our experience with the beet plant, to be of little significance and its determination as involving such large errors as to be of doubtful value.

The forms of nitrogen determined are given in the tables that follow. The variety studied was the Red Fife. We were compelled to confine our efforts to the one variety for the simple reason that we could not do any more samples while they were fresh and before there could be any question of material changes. In all cases in which the green samples had to stand, even for a few hours, we chloroformed them heavily.

A number of determinations were made, using the whole plant, but we found it quite impossible to obtain good agreement in the results because of variation in the samples as weighed out.

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TOTAL AND PROTEID NITROGEN IN GROWING WHEAT PLANT.

Crop 1913	Fertilizer per acre	Total Nitrogen Percent Stems	Leaves	Heads	Proteid Nitrogen Percent Stems	Leaves	Heads
7 July	120 lbs. nitrogen	0.4304	0.9302	0.7670	0.2579	0.6767	0.4972
7 July	60 lbs. phosphorus	0.3420	0.8214	0.6990	0.2007	0.5788	0.4320
7 July	200 lbs. potassium	0.3182	0.8282	0.7194	0.1926	0.5462	0.4537
7 July	None	0.3318	0.8146	0.7058	0.2062	0.5843	0.4483
7 July	80 lbs. nitrogen	0.3896	1.3110	0.7534	0.2742	0.9114	0.5299
7 July	40 lbs. phosphorus	0.3250	0.9942	0.6990	0.2361	0.7583	0.4755
7 July	150 lbs. potassium	0.2866	0.8078	0.6922	0.2035	0.5788	0.4320
7 July	None	0.3386	1.0186	0.6922	0.2388	0.6441	0.4863
13 July	40 lbs. nitrogen	0.3699	0.7725	0.9153	0.2633	0.4972	.....
13 July	20 lbs. phosphorus	0.3019	0.5957	0.8405	0.1599	0.3939	0.6060
13 July	100 lbs. potassium	0.2666	0.5005	0.6773	0.1708	0.3231	0.5788
13 July	None	0.2910	0.5141	0.8473	0.1953	0.3830	0.5897
21 July	120 lbs. nitrogen	0.3645	0.6909	0.9289	0.2415	0.4814	0.6387
21 July	60 lbs. phosphorus	0.2366	0.6093	0.8065	0.1436	0.4101	0.5679
21 July	200 lbs. potassium	0.2149	0.4529	0.8541	0.1505	0.3993	0.5843
21 July	None	0.2856	0.5821	0.8065	0.2171	0.3830	0.5679
25 July	80 lbs. nitrogen	0.4733	1.2893	1.0037	0.4762	.....	0.7311
25 July	40 lbs. phosphorus	0.2965	0.8337	0.8540	0.2307	0.6332	0.6550
25 July	150 lbs. potassium	0.2666	0.8269	0.8813	0.1926	0.6115	0.6931
25 July	None	0.2421	0.5685*	0.8133	0.1768	0.4265	0.6985
29 July	40 lbs. nitrogen	0.3237	0.9357	1.0105	0.2307	0.2222	0.7420
29 July	20 lbs. phosphorus	0.2312	0.6773	0.9629	.....	.....	0.7475
29 July	100 lbs. potassium	0.1986	0.5889	0.9289	0.1382	0.4918	0.6659
29 July	None	0.2421	0.7929	0.8825	0.1550	0.7094	0.6767
4 Aug.	120 lbs. nitrogen	0.2611	1.5953	1.5001	0.1718	.....	1.1446
4 Aug.	60 lbs. phosphorus	0.2366		1.3023	0.1355		1.0358
4 Aug.	200 lbs. potassium	0.1700		1.3382	0.0947		0.8508
4 Aug.	None	0.2149		1.4389	.....		1.0739
5 Aug.	80 lbs. nitrogen	0.3155		1.2961	0.2035		1.0140
5 Aug.	40 lbs. phosphorus	0.1809		1.2621	0.1055		1.0031
5 Aug.	100 lbs. potassium	0.1958		1.3573	0.1164		1.0847
5 Aug.	None	0.2339		1.1193	0.1327		0.8889

*This determination was repeated with closely agreeing results.

The ratio of the green parts and also the dry matter in the stems and heads have been given in previous tables. No attempt has been made in these data to find the relative amount of kernels and their composition, as the dry weight of the wheat as threshed and the weight of the grain, while belonging to another step in the investigation, was considered sufficient for our purposes. Had our time permitted it, there is no question but that it would have been of interest to establish the relative weights of chaff and grain in at least, the last two samples, for these plants were fully matured. The leaves had dried to such an extent that it was not longer

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feasible to make a separate portion of them. In addition to lack of time it would have been almost impossible to separate the grain from the chaff without drying which would have changed, at least, the statement of our data. For these reasons these data are probabaly more serviceable in their present form than they would have been had I changed this form for part of them.

AMMONIC AND AMID NITROGEN IN GROWING WHEAT PLANTS.

Crop	Fertilizer	Ammonic Nitrogen — Percent —			Amid Nitrogen — Percent —		
1913	per acre	Stems	Leaves	Heads	Stems	Leaves	Heads
7 July	120 lbs. nitrogen	0.0052	0.0122	0.0133	0.0054	0.0090	0.0144
7 July	60 lbs. phosphorus	0.0065	0.0101	0.0139	0.0003	0.0052	0.0112
7 July	200 lbs. potassium	0.0046	0.0122	0.0152	0.0041	0.0125	0.0117
7 July	None	0.0060	0.0112	0.0144	0.0000	0.0108	0.0115
7 July	80 lbs. nitrogen	0.0054	0.0117	0.0125	0.0030	0.0082	0.0114
7 July	40 lbs. phosphorus	0.0043	0.0125	0.0128	0.0033	0.0060	0.0098
7 July	150 lbs. potassium	0.0035	0.0112	0.0128	0.0041	0.0095	0.0122
7 July	None	0.0046	0.0097	0.0117	0.0035	0.0071	0.0095
13 July	40 lbs. nitrogen	0.0071	0.0242	0.0193	0.0060	0.0095	0.0199
13 July	20 lbs. phosphorus	0.0052	0.0131	0.0158	0.0043	0.0065	0.0169
13 July	100 lbs. potassium	0.0043	0.0101	0.0212	0.0133	.....	0.0120
13 July	None	0.0054	0.0112	0.0177	0.0049	0.0097	0.0182
21 July	120 lbs. nitrogen	0.0049	0.0144	0.0224	0.0046	0.0114	0.0166
21 July	60 lbs. phosphorus	0.0048	0.0122	0.0158	0.0075	0.0080	.....
21 July	200 lbs. potassium	0.0048	0.0154	0.0190	0.0043	0.0093	0.0146
21 July	None	0.0046	0.0136	0.0181	0.0038	0.0069	0.0133
25 July	80 lbs. nitrogen	0.0054	0.0205	0.0185	0.0063	0.0101	0.0207
25 July	40 lbs. phosphorus	0.0027	0.0098	0.0140	0.0030	.....	0.0122
25 July	150 lbs. potassium	0.0033	0.0090	0.0178	0.0028	0.0076	0.0150
25 July	None	0.0027	0.0041	0.0116	0.0024	0.0098	0.0116
30 July	40 lbs. nitrogen	0.0038	0.0131	0.0147	0.0022	0.0061	0.0095
30 July	20 lbs. phosphorus	0.0027	0.0090	0.0128	0.0053	0.0071	0.0079
30 July	100 lbs. potassium	0.0027	0.0030	0.0116	0.0035	.....	0.0098
30 July	None	0.0018	0.0063	0.0122	0.0019	0.0079	0.0103
4 Aug.	120 lbs. nitrogen	0.0071	0.0270	0.0245	0.0067	0.0110	0.0185
4 Aug.	60 lbs. phosphorus	0.0065		0.0180	0.0043		0.0154
4 Aug.	200 lbs. potassium	0.0048		0.0146	.....		0.0140
4 Aug.	None	0.0056		0.0174	0.0031		0.0139
5 Aug.	80 lbs. nitrogen	0.0057		0.0131	0.0050		0.0116
5 Aug.	40 lbs. phosphorus	0.0045		0.0161	0.0034		0.0160
5 Aug.	150 lbs. potassium	0.0050		0.0146	0.0041		0.0160
5 Aug.	None	0.0039		0.0095	0.0030		0.0122

The plants gathered on 5 August were mature, so mature that the crop was harvested on the 6th August. An inspection of the table shows that the time during which these samples were taken

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can be divided into two periods corresponding with the universally recognized divisions of development, the growing and ripening periods. The earliest samples were taken at the period of full bloom, 7 July; the latest samples were taken at the period of full maturity.

Our object in this feature of our work had two phases, one to follow the changes in the plant during the two periods just mentioned, and the other, the principal one, which we had in view, to determine the effects of the individual fertilizers upon the development of the plant and its composition. This is the reason why we used, in these experiments, no combinations of fertilizers. The object of this investigation as first proposed is to determine, if possible, what factors or factor in our conditions it may be that determines the character and quality of our wheat. It may prove to be the case that we have no justification in fact for assuming that Colorado wheat has any general character so fixed and invariable as to entitle it to recognition, either in a favorable or an unfavorable sense. This is still, to me, though the concensus of millers and bakers is to the contrary, an open question. It seems to me not only possible, but very probable that the variation in the composition and properties of samples of wheat grown on different lands in the same section may be as different as other samples from widely separated sections of the state or even from different states. In other words I doubt whether there is any standard which we can assert is characteristic of Colorado wheat. I must, however, acknowledge that the testimony of all the bakers that I have consulted is that the flour made from our wheats is an undesirable bread-making flour, falling from thirty to forty or more loaves per barrel behind flours which are first-class for this purpose. While these statements are somewhat anticipatory of subsequent work, the results of which are not yet known, they may not be wholly amiss in this place though we have presented no facts pertaining to the wheat, except those which it possibly may have in common with the plants, in respect to its nitrogen compounds.

We may consider the results obtained with the four sets of samples taken prior to the 25th July as representing the period of development of the plant, and those obtained with samples taken on the 25th July and subsequent dates up to 6th August, as representative of the changes during the ripening period.

According to the results obtained by Wilfarth, Roemer and Wimmer, it is probable that our earliest samples were taken at about the period when the crop contained the maximum amount of nitrogen, and from this period on, if their observations be correct, both the percentage of nitrogen in the plant and the total in the

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crop should diminish. Our results, taking stems, leaves and heads separately, agree with this statement. Of the sixty samples of leaves and stems given, there are only two instances in which we find any departure from this. These are found in the stems and leaves of one set of plants taken on 25th July in which, for some reason, we have high results. The heads as here given include the kernels and here we find an increase in the total nitrogen. When the period of ripening sets in we observe a rapid decrease in the amount of total nitrogen present in the stems and leaves, which is evidently not compensated by the increase in both the weight and the percentage of nitrogen in the heads. Wimmer, in the article already referred to, after pointing out the similarities and differences between the results obtained with barley and spring wheat says in regard to the total nitrogen in spring wheat at harvest time, "But here also, we find at the final harvest only 80.66 percent of the maximum amount of nitrogen previously appropriated."

What is true of the total nitrogen is also true of all the several forms of nitrogen. The one exceptional sample, already mentioned in connection with the total nitrogen, is consistent with itself throughout, i. e., all forms of nitrogen are relatively high. There is one sample that is somewhat lower than we would expect and this, too, is, in the main, consistently low throughout. These features, though interesting, did not constitute the question that we set out to determine. This question was—what effects, if any, do the individual fertilizers produce upon the composition of the plant and wheat.

Of late years, great stress has been laid upon the assumed fact that climatic conditions rather than the soil conditions constitute the principal factors in determining the composition and characteristics of the wheat grown. Our direct purpose is not to combat this idea, but to determine what the effects of nitrogen, phosphorus and potassium really are under our Colorado conditions.

It is too evident to need statement that there are fundamental conditions of climate and of soil fertility requisite to the growth of a crop of wheat and we cannot eliminate these. All that we can do is to change the relative supply of nitrogen, phosphorus or potassium under identical conditions of climate, using the same variety of wheat.

In making the preceding statement, I have the following consideration in mind: It is not just to compare samples of wheat taken on a given date unless they are of the same variety or it can be proven that they are in the same stage of development which would be exceedingly difficult to establish for different varieties. Our experience in 1914 with the two varieties, Defiance and Red

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Fife, illustrates the importance of this point. We had a shower on the 28th July, which was of very short duration, but violent. The Fife and Defiance were planted on the same day and on contiguous plots of ground. The Fife matures about eight or ten days earlier than the Defiance. This shower did not appear to affect the Fife in the least, while it very severely injured the Defiance by inducing a strong development of rust, and inducing premature ripening. The difference in the results was apparently wholly due to the difference in the development of the respective varieties. The Defiance was still in a stage sensitive to this fungus, while the Fife probably escaped injury because of its advanced development. Perhaps some allowance should be made for the different powers of resistance to this fungus possessed by these different varieties. The principal cause of difference, however, is doubtlessly to be found in the different degrees of maturity at the time of the rain. The data relative to the nitrogen tabulated above will serve to show the same, especially in regard to the stage of development.

This study of the nitrogen in the plant from the time of bloom to maturity exhibits the answer to our main thesis, i. e., that the nitrogen content of the plant is materially affected by the fertilizers used.

The plan of experimentation was as follows: Three sections of land, lying side by side and uniform in quality, were divided into equal plots and four plots in each section were sown to one variety of wheat. In our nitrogen work on the plant we have used Red Fife only. The plots in one section received the maximum amount of the respective fertilizers, those of the next section received the medium amounts and those of the third section received the minimum amounts. Our results would have been more valuable had we been able to sample the whole twelve plots at the same time, but we could not do this and our results are faulty insofar as we cannot eliminate the changes which took place between the dates on which the different samples were taken. For instance, two members of a set were taken on 7 July and the third one was taken six days later, 13 July. These samples are not, strictly speaking, comparable. Still the effects of the fertilizers on the nitrogen content of the plant and the various forms of it determined are very clear.

Every fourth plot throughout the series was a check plot, and it is the products of these plots that constitute the bases of our comparisons. An examination of the results obtained with the stems and leaves shows:

First, that phosphorus exercised but little influence upon the amount of nitrogen in these parts of the plant. This is essentially true of all the forms of nitrogen determined.

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Second, the application of nitrogen to the soil increased the nitrogen in the plant quite materially over that present in the plants grown on the check plots. This was true for each of the different applications made.

Third, the application of potassium depressed the amount of nitrogen present in the plants below that present in those grown on the check plots.

These facts hold, but not to the same extent, for the period of ripening of the grain. These statements are also applicable to the heads, though in this case we have a continuous increase in the amount of nitrogen present instead of a decrease as in the other parts of the plant. As the plants approach maturity, the differences in the amount of nitrogen present in the heads from the plants grown on the different plots becomes less certain. This is especially true of those from the plots which had received applications of phosphorus or potassium and of those from the check plots. The plants that were grown with the application of nitrates, remained richer in nitrogen in all parts throughout the period of investigation than the other plants, without any material exception.

THE ASH CONSTITUENTS OF PLANTS.

It is not proposed to follow the movement of the ash constituents in the plant, but simply to endeavor to determine in what sense and degree the amount of these constituents may be affected by the fertilizers used in our experiments. The observations given in this place do not include the kernels, only the plants. It is assumed that the amount of these constituents reaches a maximum at a certain stage in the development of the plant and from this time on decreases till the plant is mature. This is the case with the individual constituents in a very marked degree, except in the case of phosphorus, which recedes by only about one and one-half or two percent. That the ash constituents in the growing plant must be present in a soluble condition seems necessary in order that they should function, as we suppose them to do, and also that they should move out of the plant and return to the soil. We assume in this statement that these ash constituents return by the way of the plant itself and not by exudation or washing out by rain or by the dying and falling off of parts of the plants. With these questions we have nothing whatsoever to do, but simply to inquire in what sense and degree our fertilizers may affect them. For this purpose a number of samples were examined, but not all in the same manner. The first method used was to char the air-dried plant, extract with water and subsequently burn. This method gave the following results:

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MOISTURE, SOLUBLE AND INSOLUBLE ASH IN AIR-DRIED PLANTS.

Crop 1913	Variety	Fertilizer Lbs. per Acre	Moisture Percent	Soluble Ash Percent	Insoluble Ash Percent	Total Ash Percent
8 July	Defiance	120 nitrogen	8.493	6.220	2.455	8.675
9 July	Red Fife	60 phosphorus	.....	4.206	2.678	6.889
9 July	Red Fife	None	5.566	4.007	2.193	6.200
9 July	Kubanka	200 potassium	6.759	4.436	3.514	7.950
10 July	Defiance	40 nitrogen	8.652	5.165	2.612	7.778
10 July	Red Fife	100 potassium	7.428	3.340	3.651	6.991
10 July	Kubanka	40 nitrogen	8.379	3.758	2.473	6.213
10 July	Kubanka	None	7.097	4.485	2.973	7.458

The table shows that from 50.0 to 75.0 per cent of the total ash is soluble in water. This amount is not only very high but also includes a large amount of silica which separates out on evaporation to dryness. For these reasons it seemed of some interest to determine the composition of this water-soluble ash; and at the same time to determine how its quantity and composition was affected by the addition of nitrogen compared with the water-soluble ash of plants grown without any fertilizer.

In the preparation of the preceding ashes, the ground plants were first charred and then extracted. The charring of the mass of organic matter containing so large an amount of silica and alkalis might have given rise to soluble silicates and for this reason alone the percentages of soluble and insoluble ash are not conclusive in regard to their solubility in the plant before ignition. We assume it as self evident that the mineral constituents, even the silica, are taken up as solutions and that they must continue to exist in the plant in this condition till they are either appropriated by the plant, *i. e.*, used in the formation of its various constituents, or, as in the case of the silica, are deposited in the cell walls in an insoluble form. But how long they continue to remain unchanged in regard to their solubility is not known. In order to determine whether the soluble ash obtained was formed by the ignition or existed in the plant as water-soluble salts, I extracted the ground plants with warm water. The water was not in contact with the plants for more than sixteen hours in all, so that fermentative changes probably did not bring the ash constituents into solution. The aqueous extract was evaporated to dryness, the dried mass ignited and treated as usual. The extracted plants were dried and the ash in them was determined, but not analyzed further than this, that it was treated with hydric chlorid and the amount of soluble and insoluble ash determined.

Two samples were treated in this manner. One was grown with the application of nitrates and the other without the application of any fertilizer, but both were of the same variety and taken on the same date, 8th July, 1913.

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WATER-SOLUBLE ASH OF AIR-DRIED WHEAT PLANTS.

	Plants Grown with 120 lbs. of Nitrogen per Acre Percent	Plants Grown Without Any Fertilizer Percent
Ash constituents soluble in water	5.363	4.277
Ash constituents insoluble in water, but soluble in hydric chlorid	0.400	0.327
Insoluble ash (silica)	2.561	2.487
Total ash	8.324	7.091

ANALYSIS OF WATER-SOLUBLE ASH.

	Percent of Air-Dried Plant	Percent of Air-Dried Plant
Silicon	0.282	0.377
Iron	0.003	0.003
Manganese	0.002	0.001
Calcium	0.134	0.090
Magnesium	0.088	0.066
Phosphorus	0.204	0.225
Potassium	2.396	1.752
Sodium	0.035	0.028

No provision was made in the preparation of this ash to prevent loss of phosphorus and yet the water-soluble phosphorus is very high. Whether it existed in the plant as phosphoric acid or not does not appear, but it seems probable that the most of it did, and yet very considerable quantities of iron, calcium and magnesium were present in the aqueous solution, which scarcely would be the case under ordinary conditions. We know that the magnesium is a part of the chlorophyll molecule and is probably not precipitable by phosphoric acid while in this combination. Possibly a like explanation might be offered in the other cases. There is no question but that the plants grown with the application of nitrogen have larger leaves which are of a much deeper green color and yield an extract much more heavily charged with coloring matter than those grown without it. Consonant with this we find the magnesium and calcium both higher, in the plants grown with the application of nitrogen, by at least one-third.

It is a recognized fact that the application of sodic nitrate to wheat results in the production of a soft, weak straw and a tendency for the wheat to lodge. Whether this result is due to suppression of silica in the straw or to some other effect upon the growth of the plant, for instance the production of large, thin-walled cells, especially in the lower internodes of the plants, with very heavy leaves and heads is, to my knowledge, nowhere stated. The softness of the straw and its lack of harshness to the touch suggests that the silica in the straw is small in amount, whether this be the

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cause of the weakness or not. The following determinations of total silicon were made to ascertain whether and to what extent the silicon in the straw may be suppressed by an increased supply of nitrogen in the soil.

SUPPRESSION OF SILICON IN STRAW DUE TO NITROGEN.

Date of Harvest	Variety	Nitrogen Lbs. per Acre	Moisture Percent	Silicon Percent	Difference
28 July, 1913	Defiance	120	9.395	1.656	
28 July, 1913	Defiance	None	8.274	1.817	0.252
31 July, 1913	Red Fife	120	9.544	1.029	
31 July, 1913	Red Fife	None	7.564	1.236	0.207
29 July, 1913	Defiance	80	8.177	1.190	
29 July, 1913	Defiance	None	8.711	1.649	0.459
6 Aug., 1914	Defiance	120	9.802	1.192	
6 Aug., 1914	Defiance	None	9.533	1.708	0.516
6 Aug., 1914	Red Fife	120	9.724	1.134	
6 Aug., 1914	Red Fife	None	9.205	1.391	0.257
6 Aug., 1914	Kubanka	120	9.515	1.169	
6 Aug., 1914	Kubanka	None	9.550	1.557	0.388

While there is in each of these cases a depression of the silicon in the straw due to the nitrogen applied it seems too small, especially if we consider the large amount in the plant, to cause the softness and weakness noted. This statement considers only the question of the total amount of silicon present. It is possible that there may be a difference in the form in which the silicon may be present due to the action of the increased supply of nitrogen. Further, there might be a difference in its distribution in the different parts of the plant. Silicon for instance deposited in the glumes or in the blades of the leaves or in the upper portion of the stems would not tend to prevent lodging if the lower internodes were so deficient in silicon that they could not support the plants in an upright position. We assume in this statement that it is true that the stiffness of straw is due to the silicon in it.

There is a decided difference in the tendency of the different varieties to lodge. The Red Fife has scarcely lodged at all on our plots even with the maximum application of nitrogen. The Kubanka has lodged some but not badly while the Defiance has lodged badly with the minimum application of nitrogen. That this is due to the nitrogen applied there can be no doubt for in every case so far (about twenty of them), the limits of the application of the nitrogen were sharply marked in the case of the Defiance by the lodging. The amount of silicon in the whole straw, however, is fully as high as in the other varieties, so it would not seem to be a question of the total amount of silicon present.

The effect of fertilizers upon the amount of silicon contained in the first internode below the rachis indicates that the Red Fife is influenced less than the Kubanka which is in keeping with the ob-

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servation that the Red Fife resists the action of nitrogen in producing lodging or weakness of the straw. I have figures for Red Fife and Kubanka, showing the effect of fertilizers upon the amount of silicon in the upper portion of the stem, but none for Defiance.

SILICON IN THE TOP INTERNODE OF THE STEM.

Date of Harvest	Fertilizer Lbs. per Acre	Red Fife Si Percent	Kubanka Si Percent
31 July, 1914	120 nitrogen	0.535	0.543
31 July, 1914	80 phosphorus	0.559	0.612
31 July, 1914	160 potassium	0.509	0.826
31 July, 1914	None	0.508	1.174

SILICON IN DIFFERENT PARTS OF STRAW.

Date of Harvest	Variety	Part of Plant	Fertilizer per Acre	Silicon Percent
6 Aug., 1914	Kubanka	Leaves	120 pounds nitrogen	2.846
6 Aug., 1914	Kubanka	Leaves	None	3.520
31 July, 1914	Kubanka	Top of stem	120 pounds nitrogen	0.543
31 July, 1914	Kubanka	Top of stem	None	1.174
6 Aug., 1914	Kubanka	Middle of stem	120 pounds nitrogen	0.381
6 Aug., 1914	Kubanka	Middle of stem	None	0.658
6 Aug., 1914	Kubanka	Bottom of stem	120 pounds nitrogen	0.402
6 Aug., 1914	Kubanka	Bottom of stem	None	0.684

This variety, Kubanka, was chosen for these determinations because it seemingly responds to the effects of nitrogen in regard to the silicon to a less degree than the Defiance and to a greater one than the Red Fife and we assume the results to be of more general application than those obtained with the other varieties. These results show that an increase in the supply of available nitrogen suppresses the amount of silicon contained in these different portions of the plant.

There is some difference shown in the relative amounts of soluble and insoluble silicon in plants grown with and without addition of nitrogen to the soil. It seems to be the fact that the application of sodic nitrate suppresses the amount of silicon soluble in water to a greater extent than it does the insoluble silicon. This, however, is only a tentative statement based on the work that has so far been done.

The distribution of the ash in the different parts of the plant, the extent and manner in which it is affected by the application of nitrates has been studied in part, but not thoroughly. The results obtained, however, agree with those already presented, indicating that the effect of the nitrogen upon the intake of inorganic constituents by the plant is very strongly modified.

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SOLUBLE AND INSOLUBLE ASH IN PARTS OF WHEAT PLANT.

Variety	Date of Harvest	Fertilizer per Acre	Part of Plant	SiO_2 per cent	HCl. Sol. per cent	Total Ash per cent
Kubanka	6 Aug., 1914	None	Chaff	13.762	2.595	16.357
Kubanka	6 Aug., 1914	None	Leaves and sheaths	7.500	5.135	12.635
Kubanka	6 Aug., 1914	None	Top section of stem	1.986	3.892	5.878
Kubanka	6 Aug., 1914	None	Middle section of stem	1.401	3.915	5.361
Kubanka	6 Aug., 1914	None	Bottom section of stem	1.457	2.614	4.071
Kubanka	6 Aug., 1914	$NaNO_3$	Chaff	9.526	2.495	12.021
Kubanka	6 Aug., 1914	$NaNO_3$	Top section of stem	1.156	4.080	5.236

The effect of the sodic nitrate, corresponding in this case to 120 pounds of nitrogen per acre, is evidently in the same direction as indicated by our preceding data, *i. e.*, to a suppression of the silicon and a relative increase in the amount of soluble ash.

These results are the same for the later stages of growth and even for the ripe plant.

We notice that at an early stage in the development of the plant, the period of bloom, the phosphorus and silicon are higher in the plants that received no fertilizer and that the potassium is much higher in those which received an application of nitrogen.

That portion of the ash constituents insoluble in water, but soluble in hydric chlorid was not analyzed. It was, however, evaporated to dryness and again taken up with dilute acid to see if any silica had been dissolved by the hydric chlorid, which was insoluble in water. The result in both cases was negative, so it would seem that the silica existed in the plant at this time in two forms, one soluble in water and the other insoluble in concentrated acid. The soluble form is much less in the plants grown with the application of nitrogen than in those grown without it. The insoluble portion was already deposited in the cell-walls. This fact was easily observed in the microscopic examination of the properly prepared ash in which the stomata with their guard cells, the epidermal cells, the collenchymatous cells with their thickened angles, hairs and other parts were easily recognized. These various cells were apparently not so distinct, or heavily built up with silica, as in samples taken later.

It was not at first intended to extend the examination of the plants to include the mineral constituents, but the facts already stated made it advisable to include these determinations in our presentation of the effects of the fertilizers applied. The statement of the mineral constituents of the straws does not include the sulphur and chlorin, and is to this extent incomplete. These substances would have been included had we in the beginning supposed that we would have any good reason for considering this feature at all.

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The Agricultural Experiment Station

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Colorado Agricultural College

IRRIGATED AGRICULTURE IN THE SAN LUIS VALLEY

By V. M. CONE and ALVIN KEZER

(This bulletin, so far as it relates to irrigation, was prepared under a co-operative agreement between the Colorado Experiment Station and the Office of Experiment Stations, of the U. S. Department of Agriculture.)

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IRRIGATED AGRICULTURE IN THE SAN LUIS VALLEY.

By V. M. CONE and ALVIN KEZER

LOCATION AND TOPOGRAPHY.

The San Luis Valley lies in the south central part of Colorado. An arm of the valley extends a few miles into New Mexico, but is of little importance so far as irrigation is concerned. The eastern rim of the basin is formed by the Sangre de Cristo range, and the western rim by the Conejos mountains, La Garita hills, and the Saguache mountains. The junction of the Saguache mountains and the Sangre de Cristo range closes the valley in the north. The valley proper is about ninety miles long and forty-five miles wide, and is roughly elliptical in shape.

The principal streams entering the Valley on the west are the Rio Grande, Conejos and Alamosa rivers, and La Jara and Saguache creeks. Entering from the east are the Culebra and Trinchera rivers and Cottonwood, Spanish, Willow, Crestone, Rito Alto and Cotton creeks. San Luis creek flows south from the upper end of the Valley. The streams on the east are small and usually lose themselves in the sand a short distance from their canons except when flooded. The streams on the west have much larger drainage areas and carry more water than those entering

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This bulletin is based upon results obtained from field investigation and experimental farm work in the San Luis Valley, and is intended to be a popular presentation of those results. The Colorado Experiment Station, in co-operation with the Office of Experiment Stations of the United States Department of Agriculture, has been carrying on experiments and field work in the San Luis Valley for the past three years. Field plat experimental work in crops and irrigation methods have been conducted on the farms of the Costilla Estates Development Company, with headquarters at San Acacio. In this location three farms of forty acres each were divided into plats, upon which crop, soil and irrigation experiments were performed. The authors have spent considerable time upon experimental work and made many trips to various sections of the valley during the three seasons.

The Experiment Station is indebted to the Costilla Estates Development Company for courtesies extended which permitted the collection of much valuable data. In 1912 the experimental plats were taken care of by Mr. Roy Hice. Mr. E. H. Thomas was responsible for the resident work in 1913 and 1914. Much of the general irrigation information was collected by Mr. R. G. Hemphill during the years 1912 and 1913.

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from the east. At one geologic period the Valley was the bed of a lake, and all except the recently formed soils were deposited by the waters of this lake. Streams flowing into the lake were laden with this material and deposited it in fan-shaped deltas spreading outward from their canons. Except in a few cases these fans are not apparent to the eye, and the Valley appears to be a flat, treeless plain. The streams flowing into the Valley from the west being larger, but carrying less heavy material, formed deltas more extensive and flatter than those deposited on the eastern side, with the result that the trough of the Valley is considerably east of its north and south axis. Most of the large irrigation systems are located on this western slope. Here the inclination of the land varies from 5 to 30 feet per mile except near the foothills, and is so uniform that canals are usually constructed along section lines either east or north. The Prairie Ditch runs for over 25 miles in a straight line, and it is reported that at no point was an excavation of more than two feet necessary.

The elevation of the Valley is high, its lowest point being over 7,500 feet above sea level. Practically all of the farming land is at an elevation between 7,500 and 8,500 feet. Elevations of some of the principal towns are given below.

Town.	Elevation.	Town.	Elevation.
Villa Grove	7,962 ft.	Del Norte	7,868 ft.
Saguache	7,740 ft.	Monte Vista	7,650 ft.
Crestone	7,871 ft.	Alamosa	7,536 ft.
Moffat	7,568 ft.	Blanca	8,403 ft.
Hooper	7,566 ft.	La Jara	7,597 ft.
Mosca	7,562 ft.	Manassa	7,660 ft.
San Acacio	7,737 ft.	Capulin	7,800 ft.
Jarosa	7,650 ft.		

CLIMATE.

The climate is characterized by almost continuous sunshine, very little rainfall, extremes of temperature, and a high wind movement. The mean annual precipitation is between 8 and 9 inches, varying widely from season to season and at different points, the highest recorded being 18.85 inches at San Luis in 1891, and the lowest 2.88 inches at Saguache in 1896. The heaviest rainfall of the year occurs in July and August at the time when most needed. Usually the rains are of little direct benefit to growing crops, but the streams flooded from rains in the hills afford water for irrigation for a few days.

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The mean annual temperature is 42 degrees, the coldest month being January, with a mean temperature of 18 degrees, and the warmest month July, with a mean temperature of 64 degrees. The minimum temperature recorded was 34 degrees below zero, and the maximum 98 degrees above. Frosts are liable to occur any month of the year. Owing to the high altitude and rare air, these extremes of temperature are not keenly felt.

The most disagreeable feature of the climate of the Valley is the high wind, the general direction of which is toward the northeast. In some of the lightest soils the wind does some damage to newly planted crops, since it blows steadily for days at a time.

SOILS.

In appearance the San Luis Valley is a vast plain. To the eye it appears to be level and devoid of hills and irregular slopes. Actually, it is the basin-shaped bottom of an ancient lake, which at present appears as a treeless plain surrounded by high and rugged mountains. The surface slopes are unusually uniform and gradual. Close to the eastern edge, which is the low portion of the Valley, or Valley trough, the slopes are so slight that drainage is very poor, causing considerable areas of seeped land, some swampy portions, and shallow basins filled with alkali lakes.

A large proportion of the soils of the Valley is sand, sandy loams, and gravels, underlaid at from two to four feet of the surface with gravel more or less porous in nature. The soil materials were deposited in large part at the geologic time when the San Luis Valley was occupied by a lake. These materials were carried from the slopes of the adjacent mountains by the torrential streams which flowed into the ancient lake. The so-called recent soils have been deposited by the streams since the drainage of the lake, which occurred when the canon of the Rio Grande was cut thru in past geologic time. This ancient soil material was laid down in alternating layers of clay, sand and gravel. In many places at the present time the surface has been worked over and new material deposited by the streams. Some of this material is known as adobe, being of very fine texture and extremely difficult to work.

These adobe or clay soils are classed as "heavy." As a total area they are comparatively unimportant in the Valley acreage, since they are usually confined to the bottoms and flood plains of the larger streams. Away from the streams, towards the slopes in the foothills, the soils are a little lighter in texture. Most of the heavy soils are comparatively recent stream deposits—that is, they have been deposited by present streams since the drainage of the lake which once occupied the present San Luis Valley.

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Quite a large number of soil types occur, many of which have a considerable distribution. The soils deposited as the result of the work of the Rio Grande commence at Del Norte and extend eastward to Mosca, Hooper and Alamosa, and westward to the mountains. Most of these soils are rather porous and gravelly, underlaid by gravelly subsoils. In color they are mostly reddish brown. These soils have been called by the Bureau of Soils the San Luis Series.* In this region are found sands, sandy loams and loams, which the Bureau of Soils has called San Luis Sand, San Luis Sandy Loam, and San Luis Loam, respectively.

The San Luis Sand extends from the face of the mountains to the vicinity of Center and Monte Vista and eastward from those towns in narrow belts as far as the Valley trough. The type is porous and easily worked, being derived from the volcanic rocks on the adjacent mountains. The lighter portions are subject to wind drifting, and frequently form slight ridges or dunes. The subsoil is gravelly and occurs at depths of two to four feet. This soil never becomes sticky when wet, water penetrates it readily and drainage is rapid where the slopes and other conditions permit. Some of the lower slopes, due to insufficient natural drainage conditions, are swampy and alkalized. New lands of this type frequently have a cemented area or layer which occurs at about the depth of the rainfall's penetration. The cemented area has been caused by the washing down of soluble materials from the surface and their deposition in a layer at the bottom of the zone of percolation. Irrigation has dissolved these cementing materials and on old irrigated lands this layer, sometimes called hardpan, is not noticeable.

In this area the next most extensive type of soil is the San Luis Sandy Loam. This contains more fine material than the San Luis Sand previously described but is, on the whole, rather coarse and carries considerable gravel. The surface layer is from 18 to 36 inches in depth underlaid by coarse gravelly subsoil. It is quite sticky when wet, especially as there are often streaks of heavier material in the surface. Except in the lower lying districts this type is naturally well drained.

The San Luis Loam occurs in limited patches on the lower rivers and usually upon the low slopes adjoining such areas. The soil is rather heavy and contains a great deal of the finer material carried down by mountain torrents, or washed from higher lying soils. It looks much like San Luis Sandy Loam, but contains a

* Soil Surveys of the San Luis Valley, Colorado Field Operations, Bureau of Soils, 1903. Circular No. 52, Bureau of Soils, 1912.

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considerable amount of finer material, thus becoming sticky when wet. Stickiness is probably increased by the presence of alkali salts and by the absence of coarse sand or fine gravel in the surface layers. It is usually underlaid at a depth of two to three feet with sand or sandy loam which grades into the usual gravel underlying most of this region. This soil is very rich. When well drained it will produce heavy crops of grasses, alfalfa and grains, but much of it is not now available for cropping because of seepage and alkali.

The so-called Rio Grande series occurs in narrow belts along the Rio Grande. The series includes Sandy Loams, Loams and Clays, the first-named being the most extensive type. All of these soils are dark brown to black in color and usually have considerable organic matter in their native condition. The surface soils contain very little gravel, but generally at a depth of two feet or slightly over, they are underlaid with the prevailing gravel layer or layers peculiar to this region.

The surface slopes of the Rio Grande types are gentle, favoring irrigation, though they are frequently cut up by old stream courses or banks of gravel. Much of their area is subject to overflow or is flooded to increase the growth of wild hay. If protected from overflow and excessive irrigation, Rio Grande Sandy Loam is one of the best adapted soils for potatoes, alfalfa and truck crops.

The heavier Rio Grande types are also subject to overflow. They are very sticky and puddle easily, and these adverse physical conditions frequently are made worse by considerable quantities of alkali. When worked in just the right way and at the right time they give good crops of grass and wheat. However, their management is difficult as they require artificial drainage, very careful irrigation and plowing and other cultivation at just the right moisture point—conditions difficult to obtain.

The San Luis and Rio Grande Series occupy the western and southern parts of the valley and include the more important agricultural types. The soils of the northern part of the Valley are somewhat heavier in texture—that is, they contain much more fine material. They were probably deposited by slower moving streams as the present grades of the streams are much lower than those in the western and southern parts of the Valley. The lime content of the soils is also less.

The soils in this section are chocolate brown to light brown in color, although occasionally they will be found almost gray in considerable patches. Close to the mountains and on the Valley slopes the soils are gravelly to sandy gravelly loams, but on the flatter Valley floor they run to loams and clays. Rather heavy percentages

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of alkali are encountered which is mostly composed of sodium sulphate and sodium chloride. Some magnesium sulphate also occurs.

In the vicinity of the alkali lakes, in the eastern part of the Valley, there is an occurrence of some black alkali or sodium carbonate as well as some sodium bicarbonate. Outside of this small locality the alkalis of the Valley are mostly the so-called white alkalis and are occasionally in sufficient quantities to be injurious to vegetation. They come to the surface when the land is waterlogged or seeped. Probably more damage is done by seepage in many of the wet alkali sections than by the white alkali itself, although the percentages sometimes run high.

With few exceptions, the soils of the Valley are deficient in organic matter, the incorporation of which is one of the big problems of farming and successful soil management.

IRRIGATION.

Probably the first irrigation in Colorado was by the civilization which gave rise to the cliff dwellings still extant in the extreme southwestern portions of the state, but the first modern irrigation was probably in the San Luis Valley. The first development was in the extreme southeastern part of the Valley and was small in comparison with the present irrigated acreage. Some irrigation systems now in use date back as far as the early fifties, but until 1880 development was slow. The ditches were taken out by individuals or by a few farmers associated together. During the period from 1880 to 1890 a majority of the present ditches of the Valley were constructed. Little was done from 1890 to 1905, but since then new systems have been built and many of the older ones improved by the construction of reservoirs and by ditch betterments.

There are at present in the Valley approximately 1,100 ditches with adjudicated water rights. These aggregate an appropriation of 15,873.82 second-feet, while about a hundred other ditches have unadjudicated claims for water. There are about 2,000 miles of ditches and principal laterals. Authorities differ as to the area of the land irrigated in 1914, this being variously estimated at from 500,000 to 790,000 acres. Five hundred thousand acres is perhaps a conservative approximation, having been arrived at by checking up the records of agents in the field during that season. It is believed that the number of acres which can be irrigated is approximately 800,000.

During the early days of irrigation development in the Valley nearly all of the water used was secured by direct diversion from the streams, but during the past few years seventeen reservoirs with an aggregate capacity of over 260,000 acre-feet have been

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built, materially increasing the supply of water available during the irrigation season since they store water in flood times and hold it till times of normal slack stream flow.

In the western and southwestern portion of the Valley, there is considerable artesian water. Owing to the very porous nature of the soils small reservoirs cannot be built economically and successfully for storing the flow from these wells. There are between 5,000 and 6,000 of these artesian wells. Roughly, the wells average a flow of 40 gallons per minute. This is much too small for direct application except on small acreages, such as garden patches. Some of the wells, however, have much heavier flows. Despite the aggregate flow of 450 second-feet the acreage irrigated is extremely small, totaling not over 2,000, mostly on gardens and small patches. Owing to the manner in which the wells have been cased—that is, for a short distance only—it is not feasible to cap the wells and stop the flow when the water is not needed for use. Consequently the discharge from these wells has created local swampy areas and has caused considerable trouble without furnishing very much direct benefit except in the way of water for domestic purposes.

Data for 1912 show practically 300,000 acres irrigated by surface flooding. Sub-irrigation is employed directly on about 130,000 acres or approximately one-fourth of the irrigated acreage. The sub-irrigated lands are almost exclusively those irrigated from waters taken from the Rio Grande, there being only about 5,000 acres in other districts which are sub-irrigated. Furrow irrigation is used on 24,000 acres, principally for cultivated crops such as potatoes, beets and other roots, and also on lands too steep for flooding. The border and check methods are used on about 4,000 acres.

As stated above, the acreage watered directly by sub-irrigation methods is approximately one-fourth of the total irrigated acreage. However, there is no way of telling what acreage is indirectly influenced by the sub-irrigation practice. The water level has doubtless been raised over a very much larger area. Near the upper portions of the sub-irrigated belt the water table must be raised from 20 to 30 feet each season to bring it into the root zone. This practice has naturally resulted in an undue rise of the water table in lower lying lands and in seeping and swamping the lowest. Sub-irrigation can hardly be improved upon where ideal conditions of soil and slope obtain, but ideal conditions are very rarely encountered. When only a few farmers were irrigating with sub-surface methods no bad results followed, but when large areas were so irrigated it was found that sooner or later the farmer on the lower land was drowned out. Perfect control of the water level is impossible

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to secure so that sub-irrigated fields are usually either too dry or too wet. The rise of the sub-soil water following sub-irrigation has carried up alkali which has accumulated at the surface— in fact, sub-irrigation has produced more pernicious results in this respect than any other method of irrigation practiced. While sub-irrigation is very easy on the irrigator and enables one man to irrigate a large acreage at a cheap labor cost, it is very hard on the land and may be very hard on the crop. Practically all of the land which has been subjected to one system or another of drainage was formerly watered by sub-irrigation, but is now being surface irrigated.

To change from sub-irrigation to surface irrigation, it is only necessary to enlarge the supply ditches and build the field laterals closer together. For surface irrigation, especially on the lighter soils which slope, all water should be run across narrow strips of land—that is, the field laterals should be close together. In porous sandy soils the water should be run across the gentlest slope so as to reduce washing to the lowest possible limit. A change from sub-irrigation to checks or borders could be made with equal ease, the only difficulty being the expense of constructing levees. Rectangular and border checks are now being used in several sections of the Valley in alkali reclamation work.

Irrigation, especially on the sandier lands, which do not have a high water-holding capacity, must be rather frequent to give best results. Lands which tend to form a crust should be irrigated prior to the seeding, where it is necessary to "irrigate up" the crop. If this is done cultivation can be given before seeding and the seeding operation itself effects some cultivation which will produce a surface mulch and effectually break up the crust. On lighter soils where a crust is not formed there is a tendency for the formation of a natural mulch. On such soils to "irrigate up" the crop it is best to plant the crop and irrigate after seeding, because the soils will not hold moisture in contact with the seed long enough if they are irrigated first and seeded afterwards.

Until recently very little land has been leveled for irrigation. What leveling was done consisted in running a field float over the surface after plowing. Now, however, considerable land is fairly well leveled with slips and fresnos after plowing. Usually such work pays well because it permits putting all of the land into growing crop.

Clearing land for irrigation was formerly done by burning off the sagebrush or hacking it out with grub hoes. Now the land is usually broken with heavy plows pulled by tractors, and the brush is raked off. Preliminary leveling done and a crop or two planted, the ground will be settled enough for final leveling.

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DRAINAGE.

The best evidence available shows that there are approximately three-fourths of a million acres needing more or less artificial drainage. Possibly 25,000 acres are now provided with drainage systems. A large amount of the seeped land is damaged by irrigation—largely sub-irrigation. A small amount has been damaged by the flow of springs and artesian wells.

Owing to the great length of the slopes and their uniform grade drainage systems to be successful will require large districts and community effort. Drainage operations now being carried on are successful enough to warrant the statement that satisfactory drainage presents no seriously difficult engineering features. It does demand, however, widespread community co-operation.

GENERAL FARMING CONDITIONS.

The soils of the Valley have already been discussed specifically. Soil conditions for farming purposes can be summarized by stating what actually prevails. The great majority of the soils are sandy loams and gravels, underlaid by gravel. There are heavy soils in the northern part of the Valley and along the flood plains of the streams in other portions. These heavier soils often present very peculiar local conditions which are difficult to deal with but from the standpoint of the farming of the Valley they are relatively unimportant, because the area is not very great.

The gravelly subsoils where drainage is good, make the moisture situation acute since they usually cause surface soils to dry out readily, especially if the gravel comes close to the surface. Such conditions will require frequent watering in farming practice.

A general lack of organic matter or vegetable matter affects the Valley soils, except the heavier and recently formed soils along some of the stream courses. Farming practice which aims to maintain production and to increase the fertility of these soils must include some scheme for incorporating vegetable matter (commonly called organic matter) with the soil. Owing to the altitude, the seasons are short and the nights cool so that rotting of organic matter is a slow process. This has led to the general impression that manure and other organic matter cannot be rotted in these soils. This is a mistaken belief. If the organic matter or manure be thoroly chopped to pieces with a disk harrow and mixed with the surface soil, it will be well incorporated with the soil when the plowing and harrowing operations are performed. The pulverized organic matter readily rots and mixes.

The general farm practice of the Valley is to plow too shallow. Deep plowing immediately before seeding will usually delay the

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maturity of the crop, as it keeps the growth green later in the season, consequently deep plowing should be done at a considerable time before the crop is seeded. Fall plowing on lands intended for spring seeding, or at least very early spring plowing, is necessary where deep plowing is practiced. In certain localities the soils are so light that they blow readily in the prevailing winter and spring winds and it is sometimes necessary to leave such soils unplowed so that they may be protected by the stubble or other summer growth. Likewise, in some sections the winters are normally so dry that the furrow slice will be entirely dried out where fall plowing is practiced and spring irrigation will be necessary to germinate the seed. Prevailing practice differs thruout the Valley, therefore, according to the prevalence or absence of the conditions referred to. In those sections where conditions would permit more fall plowing for spring crops it would cause a better distribution of labor and larger crops.

Altho the San Luis Valley is served by two railway lines, it is necessarily subject to rather high freight rates, as lines must cross mountain passes to get into the Valley. This condition, coupled with the short season which limits the class of crops which can be grown, somewhat affects the most profitable farm practice. Cash crops in excess of local consumption should not be grown except those which will sell for an exceedingly high price on outside markets. Consequently, the best farm management to be followed in general will encourage the production of feed so that the crop is "marketed on the hoof"—in other words, to permit livestock to convert the relatively cheap hay, grain and other feed into relatively concentrated and high-priced animal products. From the standpoint of good farm practice, a great deal of these crops should be fed upon the individual farms in order that the manure may assist in the maintenance of soil fertility.

Large areas of the feed crops of the Valley are now grazed in the field. This is especially true of peas and pea-grain mixtures. Such practice is exceedingly wasteful of feed, since a large amount of it is blown away by the high winter winds and much of it is tramped into the ground. Moreover, during the winter, snow frequently covers the fields for days at a time. Under such conditions animals will often lose more in four or five days than they can gain in twenty, but where the crop is harvested and fed in lots, the waste is largely stopped.

Over a considerable portion of the Valley summer range in the foothills and mountains is available. Such a condition fits in wonderfully well with the production of hay and grains for feed upon the individual farms. It is estimated that 250,000 to 300,000

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lambs are fed yearly and if the feeding industry were properly developed the number of sheep, cattle and hogs now sent out of the Valley could be very largely increased. This could probably be accomplished by increasing the amount of stock on the smaller land holdings, rather than by increasing the large herds already in the valley. No one kind of stock holds any particular advantage over the others, altho cattle, sheep and hogs will constitute the chief market for feed crops produced.

Even in sections where livestock feeding is undertaken on a large scale it will be necessary to practice some sort of rotation by which green manure crops may assist in building up soil fertility. The best of management cannot keep the soil in high productivity by reliance solely upon the animal manures available for fertilizing purposes, since the supply of these is, in any circumstances, limited.

Crops capable of cultivation are necessary because of the prevalence of weeds and occasional plant pests and cultivation must be clean to keep down undesired vegetation, simply as a protection of the moisture supply. Incidentally, such cultivation prevents the formation of a surface crust and the moisture losses and poor physical conditions which result from such formation.

ROTATION.

In starting a rotation it must be kept in mind that perennial crops, such as alfalfa, should be seeded only on well-leveled land, consequently, in starting a rotation on new land or on old land which is improperly leveled, annuals should be used at first, thus permitting time being spent for proper leveling of the land for irrigation. Peas is one of the best crops available for the first planting on new land or to start a rotation on old land, is an excellent feed crop, and is also an annual. Alfalfa should never be seeded until the land is well leveled, because poor levelling results in irregular stands and bad conditions for watering—some parts will be killed out because of excess water, and others will do poorly because of a lack of water. Since alfalfa is a perennial and will probably occupy the land for several years it should be put in with that expectation. A rotation may then be practiced on the portion of the farm not in alfalfa, while the latter may stand until its yield commences to weaken. In other words, alfalfa should form part of a long rotation, while the rotation of peas, grain and cultivated crops should be shorter. In the shorter rotation, peas or pea-grain mixtures should be the first crop on the land. Potatoes, if grown at all, should follow peas or alfalfa. Where peas is grown some trouble is experienced with weeds, especially if the crop is grazed. Harvesting the peas takes the weeds off before seeding, permits early

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fall plowing, and gives much the same effect as a cultivation, since it cleans the land of weeds and permits an actual cultivation in the shape of plowing.

Grain for the most part should be grown only for feed or seed. A small amount can be reserved for a cash crop to supply local demands. Where grain is used it should follow peas and pea-grain mixtures, or alfalfa where old fields are being broken up and new stands established.

At present there is a strong tendency to farm larger areas than is advisable with the help and capital available. In most cases a reduction of the size of the farms with better rotations and farm management, would result in large returns.

Sub-irrigation appeals strongly to the average man. In fact, the sub-irrigated districts have been called "the lazy man's paradise." It is the *brag* of some of these "lazy men" that they "can turn on the water and go fishing for three weeks." Sub-irrigation permitted the early settlers to farm large areas, but it resulted in the destruction of the fertility or the seeping of the lands themselves. Surface irrigation, while requiring more work, will *live* much longer and return heavier crops. Sub-irrigation on new lands when first applied will often produce enormous crops, but the yields are certain to run down, except under the most favorable conditions, unless ways of keeping up the fertility are employed. This means that more capital and more labor must be applied to individual units of land to even make profits over most of the districts where bonanza farming formerly prevailed. There has been a noticeably marked change in sentiment on this matter the last few years.

It is fundamentally important that farmers in general raise more of their own living. The hardy garden vegetables do wonderfully well under irrigation and possess a quality scarcely to be surpassed, yet there are not nearly so many gardens as there should be. Every farm should have a good garden and, whether the general farm crops are fed or not, each farmer should have some chickens, a few cows, and a few pigs so that all eggs, butter and meat used in the home will be produced on the farm and small surplus of poultry and dairy products may help reduce the grocery bill.

The leading farm crops in the Valley are wheat, oats, barley, native hay, field peas, and potatoes. Alfalfa has increased remarkably in the last three years, and sweet clover has attained a wide distribution. Sugar beets were formerly grown, but their production has been abandoned, not because they were not adapted to Valley conditions and soils, but because the population was not ready for the intensive garden culture necessary to grow sugar beets suc-

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cessfully. Some planning for the future was necessary so that the organic matter in the soils might be built up. Deep plowing and frequent cultivation were needed for success, in addition to a great deal of hand labor. These requirements were not met in the Valley, and the beet industry has been a failure. Disease has made potatoes an uncertain crop. They were formerly staple.

ALFALFA.

It was formerly supposed and quite commonly asserted, that alfalfa could not be successfully grown in the San Luis Valley, but the folly of this belief has been amply demonstrated in the past few years, and it is now known that the crop can be grown practically everywhere in the Valley. Fields of some years' standing may be found in nearly every section at the present time. From Del Norte on the west and Hooper and Mosca on the east; from Saguache and Moffat on the north to Antonito on the south, and San Luis, San Acacio and Eastdale on the southeast, there are successful fields of alfalfa. Many of the failures in the past have been due to a lack of understanding of proper methods of handling the crop and to improper varieties.

The altitude of the San Luis Valley is very high and the extremes of temperature and moisture are consequently great. The southern types of alfalfa and much of the so-called common alfalfa are not likely to prove successful because of their inability to stand the winter climate and the dry cold, windy springs.

Alfalfa is a deep-rooted crop. Where the root room is limited by subsoil water, the common alfalfas will not survive. The so-called hardy or northern types will grow under these conditions, but the reduction of root room causes them to feed heavily upon the surface soil, and all except exceedingly rich soils will soon be exhausted. Alfalfa is commonly supposed to be a soil improver, renovator or fertilizer. Under proper conditions this is absolutely true, but it is also true that of all the crops grown in the Valley alfalfa is one of the heaviest feeders upon soil fertility. It may be expected, therefore, that on those soils where the rise of sub-soil moisture is such as to develop a very heavy shallow root system, the crop will eventually tend to exhaust the soil fertility. Many of the Valley soils, as has already been shown, have sandy and gravelly subsoils. On such soils, when the subsoil water is allowed to recede (if it does recede) the mass of roots in this narrow zone at the surface finds difficulty in securing moisture enough for the plant to subsist upon. Growing upon these porous soils the crop is unable to put roots down into the gravelly layer fast enough to get the water needed for growth and the thick mass of roots in

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the surface will soon exhaust the water supply in the limited area of the surface soil. Under such conditions the crop ceases growing and will perhaps wither and die. While proper varieties can be grown where the subsoil water is very close to the surface, they will not make as good development nor produce as heavy tonnages thru so long a period of time as will be the case when the soils are watered by correct methods. Where the farming methods are such as to provide a considerable depth of soil properly moistened, alfalfa sends out an extensive root system which enables it to draw its moisture and food supplies from large areas of the soil and subsoil. These are the conditions best suited for the proper and heaviest development of the crop.

Under best management it is not advisable to seed alfalfa on new land or on old land that has not been properly leveled. Alfalfa is a crop which will remain on the land several years. Improperly leveled land increases the work of irrigation and will often leave pockets which will receive so much water that the alfalfa will be killed. On the other hand, ridges and knolls may be left to which water cannot be supplied in sufficient quantity to keep the crop going. These conditions increase labor and reduce the yield of hay.

An additional reason exists for delaying planting on new lands. When first broken up and put under irrigation, these settle unevenly. They should therefore be irrigated at least one or two years so that these inequalities can be leveled off and settling effected by the use of irrigation water may be finished before the ground is planted to alfalfa. Such practice will do away with the evils which often appear from gopher and other rodent holes before the alfalfa is put on the land.

In San Luis Valley it is seldom advisable to use a nurse crop with alfalfa. Generally only two conditions occur where the use of a nurse crop is advisable, these being found upon the heavy abode and clay lands which tend to bake and crack at the surface. Here a nurse crop may break up the surface and enable the young plants to appear, which they might be unable to do otherwise. In sandy lands which are subject to plowing, it is sometimes advisable to put in a nurse crop to hold the surface soil. Under practically all other conditions alfalfa will do better and can be more successfully started when planted by itself.

Variety.—Both the costly experience of farmers who have made failures and the direct experiments by the Experiment Station have shown that it is not advisable to plant the southern types of alfalfa in the Valley, and, in general, even common alfalfa is not adapted to the soil and climatic conditions which are found there.

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The best varieties to grow are the Baltic, Grimm, and Hardy Turkestan, in the order given considering local preference or comparative value for the Valley conditions. Baltic alfalfa is, in a way, a selection from Grimm, but is somewhat better than the parent variety. Common alfalfa, the seed of which has been obtained from long established fields from which practically all of the non-hardy plants have been killed, can be grown to a considerable extent, but it is not advisable to use common alfalfa for seed if the hardy varieties can be obtained and their propogation effected. Such "naturally selected" common alfalfa will stand the winters very well, but it does not stand the soil water conditions nor the effects of late spring frosts, which are often accompanied with *Black Stem Rot* or *Alfalfa Blight,* as well as do the hardy types.

Preparation of Seed Bed.—One of the first considerations in the preparation of a seed bed is to have the land properly leveled. After this feature has been taken care of, the immediate preparation will depend a great deal on previous cultivation. Relatively new lands should be deeply plowed, preferably in the fall, where alfalfa is to be planted the following spring. Sometimes in preparing a seed bed it is advisable to plow deeply and thoroly for a grain crop and then disk the stubble of the grain in the fall after the grain is removed and the following spring drill the alfalfa in on the land so prepared. This is especially advisable for sandy lands, and will do away almost entirely with any need for a nurse crop. Where land has been plowed it should be worked down thoroly by disking and repeated harrowings until the sub-surface is well packed, with a granulated surface to conserve moisture and to prevent, as far as possible, the winds from blowing the soil.

Sometimes there is sufficient spring moisture in the soil to germinate the seed and start the crop off. In such cases planting may be done at once. Where the soil holds insufficient moisture, as is often the case after dry winters, it may be necessary to irrigate for seeding. On heavy adobe or clay lands, or even heavy loam lands, it is advisable to thoroly level and prepare the land, irrigate, and then, just as soon as the surface can be worked, plant with a disk drill. If such a tool is not available, it is advisable to disk the surface and follow the disk with a harrow and alfalfa drill or seeder.

In the case of sandy lands it is usually best to thoroly prepare the seed bed, seed the alfalfa and irrigate afterwards, because on sandy land there is no danger of the formation of a crust and sand is not retentive enough of moisture to hold moisture in contact with the seed any great length of time consequently the seed should

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be in the ground previous to the irrigation. This process is commonly called "irrigating up."

In the San Luis Valley spring seeding should always be practiced. It is usually advisable to delay seeding until the latter part of April or early in May, as the soil is then warmer and the crop will start up more vigorously if other conditions are right.

Irrigating.—The first year, especially, care should be taken in watering. The object should be to make root rather than top development. To accomplish this there must be water in the subsurface and subsoil, because the roots will not grow downward into a dry soil. Frequently very light irrigations will keep the crop growing, but will not tend to produce root deevlopment. Relatively heavy irrigations, followed by lighter ones, will tend to produce a heavy root growth.

One of the most serious dangers to alfalfa is winter killing or more properly, spring killing, due to the dry, cold windy springs. To reduce this danger, it is advisable to irrigate in late September or early October, so as to have some moisture in the ground upon the approach of winter. A crop so irrigated will start off vigorously in the spring. Irrigation should be such as to keep the crop growing energetically thruout the season. When the spring is dry, early irrigation is necessary. Where considerable winter or spring precipitation has fallen so that abundant moisture is in the soil it is advisable to withhold the early spring irrigation because the water at this season is exceedingly cold and will retard plant growth.

Usually three cuttings may be obtained in a season, or two cuttings and enough later growth to make considerable pasture, the latter often amounting in value to more than half a cutting. For this amount of growth, two or three irrigations will ordinarily be sufficient. On new land which has not been irrigated previously or on land very deficient in vegetable matter, more than one and one-half acre feet of water will probably be needed to produce maximum crops. Under most other conditions, however, one and one-half acre-feet will probably be ample to grow a maximum crop and may be found to be more than is absolutely necessary in the short seasons which prevail in these altitudes. Alfalfa will give heavier yields and will survive much longer if proper methods of surface application of water are followed. It will make better root development, and with better root development is capable of giving better yields. Sub-irrigation frequently used in the Valley holds stagnant water in contact with the subsoil for long periods. Alfalfa roots are killed out in such standing subsoil water, but they will grow to great depths in moist subsoils which do not have sufficient water to stagnate.

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Harvesting.—One of the first essentials in growing alfalfa is to know when to cut it. The proper time to cut to get the greatest total yield of hay and feed for the season is when the crown shoots which are to produce the following crop make their first appearance. An examination of the crowns at the soil's surface from time to time will determine this point. The blossoming period is not a safe criterion to follow, because weather conditions markedly influence the time of blossoming. Sometimes the crop will be in full bloom before the crown shoots appear, and sometimes the crown shoots will be out before more than the first blossoms are in evidence. If the alfalfa is allowed to mature too much for any particular cutting it will retard the development of the succeeding crop. While any individual cutting will give a greater amount of tonnage if allowed to go to full bloom, the total weight of cuttings during the year will be greatest and the hay will be of much better quality if the alfalfa is cut upon the appearance of the first crown shoots.

The best method of making hay is to mow after the dew is off in the morning or afternoon; then rake with a side delivery rake very soon after the alfalfa is cut. It should only be allowed to wilt slightly before raking. The cutting process thru which alfalfa must pass is essentially drying. The leaves are the natural organs of alfalfa for getting rid of moisture. If the alfalfa is allowed to lie in the swath until the leaves are dry it takes a long time—several days—to dry the stems out. When thrown into a loose windrow with a side delivery rake most of the leaves are in the shade and will continue to evaporate moisture rapidly so that the curing or drying will take place in a very much shorter time. The alfalfa can be stacked directly from the windrow or may be cocked, depending upon the particular farm conditions. Where the old dump rake is used it is advisable to rake after the hay is slightly wilted, and put the hay into small cocks as quickly as possible, and cure in the cock. When handled in this way, especially where the side delivery rake is used, the hay can be put in the stack from twelve to twenty-four hours after cutting, which very much reduces the work and facilitates the whole process.

Black Stem Rot or Alfalfa Blight.—In the spring of 1914 alfalfa made an unusually good growth early in the season because of favorable weather conditions. A heavy frost, however, struck the Valley May 9th. A few days after this frost many growers noticed that their alfalfa was not growing properly. One of the authors, with Mr. A. C. Cooley, at that time Valley Agriculturist, drove over practically all the western and central sections of the Valley examining fields. It was found that the difficulty was

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caused by Black Stem Rot or Alfalfa Blight. This disease attacks the alfalfa following a heavy frost which cracks the epidermis or plant skin on the stems, thus making it easy for the disease to gain entrance. The disease is almost never troublesome except after heavy frosts in the spring time. The only remedy known at present is to mow the hay at once, no matter what the size of the cutting, because the Stem Rot retards or prevents the growth of the crop on the land, especially if very virulent, and it may kill out the crop entirely. Mowing obviates this trouble and prevents injury to succeeding crops.

PEAS.

Field Peas, or Canada Field Peas, is one of the best crops for the Valley. Before it was discovered that alfalfa could be successfully grown field peas was almost the only legume crop successfully and generally planted. While authorities differ somewhat as to the time of introduction and as to the responsibility for the orginal plantings, it is generally conceded that some of the first planting was done in the vicinity of Monte Vista, and it is certain that the value of peas as a crop was first thoroughly established in this vicinity. James A. Kelly was one of the first to put out peas as a crop and to successfully feed it to stock. In 1914 peas constituted the major portion of the feed for something over 260,000 sheep fattened for market, while it is estimated that 18,000 to 20,000 head of cattle and a large number of hogs were also fattened on this crop as the principal feed.

When peas was first introduced the Valley had just reached a period when injury was being felt from continuous grain farming. Peas helped to restore the soil fertility and made a good rotation crop. It is quite probable that peas must be given credit—and a very large credit at that—for saving the agriculture of the San Luis Valley at a time when it was in extreme danger of annihilation because of reduced soil fertility.

The common practice over much of the pea district is to disk peas into the grain stubble and not plow. This method has some advantages, but on the whole is slipshod and will not produce the greatest possible results. Frequently, under the methods of subirrigation prevailing in some localities, this method will give greater returns than better ones, but where proper surface irrigation is employed much more satisfactory yields can be obtained where the land is properly prepared for the crop. To be successful, peas should be planted just as early in the spring as the seed can be put into the ground. In order to accomplish this to the best advantage the land should be plowed in the fall. One of the best reasons for

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early planting is that peas is a cold weather crop; that is, the plants grow and make their best development in the cool spring weather. When planted late they are blossoming and developing seed at the most heated period of the season. As a consequence there is a tendency with late planting to a heavy production of vines and a light production of seed.

In order to plant early and properly it is necessary to plow in the fall or exceedingly early in the spring. The seed bed should be worked down until it is fairly compacted. The peas should be drilled in. The amount of seed per acre to give the best results will vary widely in different localities. On new lands, especially, more seed is required than on land that has grown peas for a number of years. This is due partly to soil fertility and is partly a question of inoculation. On new lands the soil is not inoculated for peas. When peas has been grown on the land for several years there is plenty of inoculating material present so that a smaller amount of seed will produce a larger number of plants.

Probably sixty pounds of seed peas per acre will be sufficient unless the crop is to be raised on new lands, where it may be advisable to plant as much as ninety pounds per acre. On many of the richer old lands which have been growing peas for a number of years, as low as thirty-five pounds per acre is amply sufficient.

Varieties.—There is an exceedingly large number of varieties of field peas, but despite this only a comparatively few have received very wide distribution. The two varieties most widely grown are the so-called San Luis Valley Stock Pea or "Mexican," and the White Marrow Fat, or Colorado White. The so-called Mexican pea is not a pure variety, but consists of a large number of mixed sorts, and for adverse conditions, is probably the best one to plant. Where conditions are good for pea growth, the White Marrow Fat will make heavier yields.

Numerous other varieties have been tried, some of which give considerable promise, but there is a large opportunity for improvement by seed selection. Considerable work has been done by individual farmers and a little work by the Experiment Station. This has not yet resulted in many new sorts, but it has been carried far enough to show that there is possibility of heavy increases thru selection breeding. The Warshauer-McClure Sheep Company of Antonio has been hand-selecting a variety. They have obtained a large white pea which matures at least two weeks earlier than the common peas. It does not make as heavy a vine growth, but pods very heavily. Farmers who have hand selected their peas claim that they have obtained heavy increases in yield over those not hand selected. The selection of high yielding individual plants to become

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the mothers of varieties will probably give quick and much heavier results than any hand bin-selection that could possibly be made. In this way only high yielding plants would be kept to start the variety, while with bin-selection a certain type of seed is obtained, having both high and low yielding plants, which does not give the greatest possible increases.

Peas should be planted with a drill—preferably a disk drill. Being large seeded, they can be planted from two and one-half to three inches deep, which will insure the seed moist soil, if proper care has been taken in the preparation of the seed bed. A common practice in drilling peas is to stop up every other drill hole. Thus with a drill having the shoes or drills eight inches apart the peas would be drilled sixteen inches apart where every other hole is stopped. In experimental work the past two seasons in the Valley it has been found that practically as good, and sometimes better results can be obtained by leaving all the drill holes open. For new lands, to leave all the drill holes open is better practice and for most old lands it is just as good as the other method.

The type of drill with the so-called revolving cup feed should be used for pea planting, as it will not break the seed. The fluted roller type of feed will crack a large proportion of the peas and thus be very wasteful of seed.

Irrigation.—Enough water should be present in the soil to start the crop in the spring even if irrigation must be practiced in order to put the water there. Any irrigation made should supply sufficient water for continuous unchecked growth until the time of blossoming. To produce the heaviest grain yields, irrigation should be shut off at this time. Heavy supplies of soil water after the plants are in blossom will keep the crop growing and blossoming clear up until frost. It will increase the yield of vines, but will reduce the yield of peas. The water can be handled much better and controlled much more easily if surface irrigation is used and heavier yields of both peas and vines may consequently be obtained. With sub-irrigation there is danger of getting too much water which is liable to be held on the land too late to make the best development of peas. The reason why peas disked into stubble land have apparently done better in many instances than peas planted on plowed land, has been largely due to sub-irrigation, the stubble land having prevented some of the effects of excessive moisture which usually accompanies sub-irrigation.

Harvesting.—The common practice in the Valley in the past has been to graze stock, either hogs, sheep or cattle, on the peas in the field. In general this practice is wasteful. In the first place, many of the leaves dry up and blow away, causing an actual loss

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of feed. A quantity of the peas themselves is lost by tramping into the soil. There is another disadvantage: A five days' snowstorm quickly burying the peas in the field may cause more loss to the animals than they could gain in twenty days' grazing. Sooner or later all growers must practice cutting their peas, because, if for no other reason, they can get very much more feed off the same acreage where the peas are cut and properly taken care of than when they are grazed in the field. Another very decided advantage exists in cutting. Pea fields are often very weedy, especially with sunflowers, so that the crop following peas is liable to be troubled with weeds. Where the peas are cut and stacked this difficulty is not important, as cutting gets rid of the weeds, also leaving the land in shape so that it may be plowed and prepared for spring crops.

Pea-Grain Mixtures.—What has been said in regard to the preparation of the seed-bed and irrigation for peas applies equally well to pea grain mixtures. Mixtures which have been used extensively consist of pea-oat; pea-barley; pea-oat-barley; pea-wheat and pea-wheat-barley. One of the advantages of planting grain with peas is that the peas more or less thinly occupy the land and some other growth will be present anyhow, consequently the grower might just as well harvest a desirable feed by planting some of these grains with peas. Peas make a nitrogenous feed stuff and consequently make a very narrow ration, but when planted with grain mixtures a feed is harvested which is much more nearly balanced. Thus not only the tonnages are increased, but a better feed is produced.

For pea-oat mixtures on new lands, heavier amounts of seed will be needed than on land which has been growing peas for some time. A mixture of about forty-five pounds of peas with twenty to twenty-five pounds of oats; forty-five pounds of peas to twenty pounds of barley; forty-five pounds of peas to fifteen pounds of oats and fifteen pounds of barley; forty-five pounds of peas and twenty pounds of wheat; forty-five pounds of peas and fifteen pounds of wheat and fifteen pounds of barley are about right for new lands. On old lands, thirty to forty pounds of peas should be used with fifteen to twenty-five pounds of oats; fifteen to twenty pounds of barley, and fifteen to twenty pounds of wheat.

Early seeding is as important with pea grain mixtures as it is with peas alone. Oats may be killed out by frosts on exceedingly early seedings, but usually barley and wheat will withstand frosts. This has been the experience in experimental work with such mixtures.

The pea-grain mixtures should be harvested in the same manner as peas, and should be either stacked or put into the silo. The

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pea plants, especially if the growth is rank, often become very much tangled and are difficult to cut. This difficulty can be very greatly decreased by the use of pea guards on the mowing machine sickle bar. These raise the peas up so they are cut off squarely. Where stacked it is necessary to rake or at least cock the peas for curing.

Harvesting should be done at a time when the greatest quantity of peas may be saved. There are always some pods which ripen later than others and cutting should take place at a time when the greatest possible number of developed pods may be obtained. The peas and grain mature to the proper stage for cutting at practically the same time.

When put into the silo peas are allowed to mature to about the same stage, cut, raked, and taken immediately to the silo. Even then, it is often necessary to run some water in with the peas to make them keep successfully.

WHEAT.

Wheat as a crop has a place on practically every farm in the Valley, as it fits in well with rotation and will make a feed or cash crop almost every year. It has been amply shown, however, by past experience in the Valley that wheat should not be grown as an entire crop. In some sections wheat has done exceedingly well, and was planted extensively and often the entire acreage of not only one farm, but of hundreds of farms, was planted exclusively to it. Naturally under such management the soil productivity declined. Wheat cannot be grown continuously on any soil in any climate. Without a rotation of some sort disaster will arrive sooner or later. However, as a crop occupying part of the farm acreage and a place in the rotation, wheat has a great value.

Winter Wheat.—Winter wheat has not been grown extensively in the Valley. It might be utilized to a greater extent. The only varieties worth considering at present are those belonging to the Turkey type, Turkey Red and Kharkov being the best. Land for winter wheat should preferably be plowed in July or early August. Plowing should be deep. Frequently it would be advisable to follow the plow with a disk harrow. Seeding should be done the last half of August, while successful plantings and successful crops are often made with much later seeding; but the practice is not advisable in the length of season which prevails, as it will result in failure many times when earlier planting will be successful.

Seeding should be done with a drill, preferably and on most lands with a disk press drill, using sixty pounds of seed per acre.

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On very heavy lands it is sometimes not advisable to use the press wheels, but cover with chains or other devices. Under other conditions the press drill is to be preferred.

Spring Wheat.—Practically all of the spring wheat grown has been Defiance. The famous Marquis wheat has been tested. This variety matures in a season from ten days to two weeks earlier than Defiance and has a better quality of grain, but under good cultural conditions does not yield nearly so heavy a crop, consequently, for most conditions Defiance is the preferred variety.

Spring wheat should follow peas, or cultivated crop in the rotation. Where the soil moisture is such as to permit fall plowing without undue blowing by winds during the winters the land should be fall plowed so that early spring seeding may be done. Seeding should take place quite early in the spring, in March and April, if possible, injury by early frosts being little to be feared.

Preparation of Soil.—Land for wheat should be plowed rather deeply a considerable time previous to planting. Fall plowing accomplishes this for spring wheat, altho following dry winters land fall plowed may be rather dry for seeding in the spring. This is really the only objection that can be offered where winds do not need to be considered with a specific soil. Prior to seeding, land should be well compacted by disking and harrowing so as to provide a firm seed bed. The preparation of land for wheat, oats, barley, spring emmer and other spring small grain crops should be much the same. Spring wheat should be seeded at the rate of about ninety pounds per acre for most irrigated conditions of the valley. If a smaller amount is used, the stand will be so thin that weeds will take partial possession; if more is used, the stand will be so thick that the grain itself will act as a weed and reduces the yield by undue competition.

In general the care of seed thruout the valley is extremely lax. Seed is often mixed with barley, oats, peas, wild peas and other impurities. More care directed to screening and grading the seed would result in much more satisfactory crops.

Irrigation.—In the spring if the ground holds moisture enough to keep wheat growing, it should not be irrigated. An irrigation should be given, however, just as soon as water is needed. In other words, the wheat should be kept growing continuously. Irrigation should stop at the blooming period and in no case should water be applied after the grain has reached the soft dough stage, except on almost pure gravel patches. Late irrigation deteriorates the quality of the grain and prevents proper ripening.

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Proper surface irrigation will return heavier yields than sub-irrigation, because of the better aeration of the soil and increased root room which this method will give.

Harvesting.—Occasionally a wheat crop will be caught by early frosts so as to render it unfit for milling purposes. Under such conditions it is sometimes advisable to harvest for hay. Wheat cut in the soft dough stage and cured makes an excellent quality of very palatable, nutritious hay. When not caught by frosts wheat should be cut in the yellow ripe stage. Stacking is advisable unless thrashing out of the shock can be done within one or two weeks of harvest.

After the wheat is removed there will usually spring up many weeds, especially on the older lands. To prevent the seeding of these weeds and to preserve moisture and fertility it is well to disk the stubble and plow.

OATS.

The cool climate of the Valley is especially favorable to oat production where soils have been kept up in proper fertility. The straw, after the grain is thrashed, makes very good feed, almost as good, in fact, as a great deal of hay grown in lower altitudes.

The preparation of land for oats is much the same as for wheat. Oats should be seeded a little later in the spring than wheat as it is more liable to injury from spring frosts. It is safe to seed in April and even as late as early May if seasonable conditions warrant. The order of planting with most of these crops should be barley, wheat, emmer, oats, as oats will stand the least frost of any of the crops.

What has been said in regard to irrigation for wheat will also apply for oats.

Varieties.—The two varieties that give the greatest promise for the Valley are the Colorado Number 37 and the Kherson. Colorado Number 37 is a Swedish type. The original selection from which it was originated was made by the Colorado Experiment Station in the San Luis Valley and the variety is consequently well adapted for Valley conditions. Kherson is the earliest maturing variety grown in Colorado. It has given very good results and heavy yields of grain. The production of straw, however, is very much less than in the case of Colorado Number 37, but either of these varieties is good.

Growers should follow community growing to a considerable extent—that is, a neighborhood should grow either one or the other of these varieties in order not to have mixed seed or mixed grain. The Colorado Number 37 will probably do best on the

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heavier lands. As the soils commence to get lighter Kherson will be the preferred variety. Kherson will do better at the higher altitudes.

Many other varieties of oats, such as the New Market, the Big Four, the Swedish Select, all do fairly well. It would be best, however, for valley growers to confine their selection to the Colorado Number 37 and the Kherson, the two best adapted varieties. Oats are excellent feed and also make a very high quality of hay if cut for that purpose.

Seeding.—The amount of seed to use per acre will depend somewhat upon the variety. Large plump seeds require heavier seeding than smaller ones, but about eighty pounds of seed per acre is the average amount to plant. With very large seeded Colorado Number 37, it will sometimes be advisable to sow as much as ninety pounds or even more to get proper results, because the larger sized seeds run fewer to the pound.

BARLEY.

During the past few years barley has been more or less an uncertain crop in the Valley, altho in general it has been very well adapted to the soil and climatic conditions. However, barley is easily affected by changes in soil and soil fertility, and in recent seasons very deficient barley growths have been secured. The liability of the recurrence of this trouble is the strongest objection that can be urged to barley as a feed crop, but owing to this objection barley will probably be found most valuable as a crop to plant with peas. For this purpose the so-called beardless barley is to be recommended, as the absence of beards is very desirable in feeding hay or straw to animals.

All of the bearded varieties, Hanna, Oderbrucker, and California do well and produce in normal seasons rather heavy yields of thrashed grain.

Seeding.—Barley can be seeded as early in the spring as peas without probable danger of injury from frosts. The earlier planted barley seems, in fact, to make a better growth and to be less injured by seasonal conditions than that planted later. This has been true on experimental plats near San Acacio for the past three years. Barley may be planted in late February or early March if seasonal conditions permit. When planted alone, about ninety-five pounds of seed per acre is required for all of the hulled varieties. Where the berry is exceedingly large, more pounds may be needed, and where exceedingly small a slight reduction in the amount of seed can sometimes be made profitably. With the hulless varieties less seed is required, seventy-five to eighty-five pounds being usually sufficient.

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Irrigation.—Barley is more sensitive to changes in the water supply than any other of the small grain crops. A lack of water just at the proper time will always stunt the growth and irrigation should be such as to permit a vigorous continuous growth.

Harvesting.—Barley is sometimes harvested as a hay crop. When the bearded varieties are so harvested they should be cut relatively early. If they are allowed to mature until the stiff dough stage, the beard is liable to be a serious obstacle to successful feeding. The beardless varieties can be cut anywhere from the soft dough to the stiff dough stage and made into good hay.

When cut for grain they should be allowed to get to the yellow ripe or well past the stiff dough stage before cutting. Except in years of short straw growth, barley will be cut with the binder or header. When conditions are such as they were in 1913, when a very short growth of straw was produced, much barley can be harvested only with a mowing machine.

EMMER.

Experience with winter emmer in the Valley is not sufficient as yet to justify its recommendation for general planting. Difficulty seems to be encountered in getting soil conditions such as will prevent severe spring killing. With the soils dry and with windy weather in the spring, spring killing is almost a certainty. Conditions have not been sufficiently favorable to warrant recommending the crop except in favorable locations.

Spring Emmer.—Spring Emmer gives promise of being a strong rival of barley as a grain feed crop. Emmer belongs to the wheat family. The hull, however, sticks to the berry when the grain is thrashed, this peculiarity distinguishing it readily from the common wheats.

Preparation of the land and irrigation are the same as for wheat. Emmer can be seeded as early as wheat, about ninety-five pounds of seed per acre being used. It may have some value as a hay crop in occasional years, but if grown at all it should be for a grain feed.

RYE.

Winter rye gives promise of being valuable as a feed crop both for the straw and grain. It should be planted on land prepared the same as for wheat and at about the same time. From 60 to 70 pounds of seed per acre should be used. Irrigation should be about the same as for winter wheat. The larger proportion of the small grains production in San Luis Valley is for feed. Except to raise seed and to have a grain feed to be used separately, the most of the

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plantings may well be in pea-grain mixtures, to which reference has already been made.

SUGAR BEETS.

Sugar beets have been declared a failure for the San Luis Valley. The factory built at Monte Vista and operated for a short time is now idle, partly because of financial conditions, but largely because of the inability of the factory to get beets. The sugar beet crop must be looked upon and treated as a garden crop if successful and profitable yields are to be produced. There is no fundamental reason why beets should not do well in the Valley, but to produce them profitably it is necessary to put the soils in proper tilth and a high state of fertility. The Valley soils contain abundant mineral constituents, but for the best production the soils must also have incorporated in them organic matter in considerable amounts. With the proper incorporation of organic matter, deep and thoro plowing and proper cultivation and irrigation, sugar beets might be a successful crop, but with present methods of management the yields generally will not be heavy enough to induce growers to produce them.

Upon many farms it might be desirable to grow some sugar beets, or preferably stock beets or Swedish turnips, to help out the winter supply of succulent feed. Sugar beets, stock beets and stock turnips all do well on land properly prepared and cultivated. Until a larger proportion of the community is willing to adopt the methods necessary, these crops should be planted in very small acreages, as they are expensive of time and labor.

POTATOES.

In the past potatoes have been considered an excellent crop for the Valley conditions. Some world's record potato yields have been produced. In the past few years, however, blight and other diseases not yet understood have made yields very uncertain. Potatoes make a very poor crop for new lands. When grown at all they should be planted on lands which have been under cultivation for some time—preferably lands which have produced several crops of peas or been in alfalfa or sweet clover.

Potatoes as a market crop are only adapted to the more sandy lands. On such soils as have had their fertility built up by proper rotation of peas, alfalfa or sweet clover, potatoes are still a good crop when prices are good and diseases absent. Whether or not they should be grown is a question for each farmer to settle for himself because of the general uncertainties of production and marketing. Owing to the short season, potatoes should be planted early, preferably early in May. Under Valley conditions, whole

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seed should be used. The varieties which are best adapted to conditions are not always the best market varieties, but the Pearl, the Charles Downing, and the Irish Cobler, are among the best varieties.

Potatoes should never be irrigated by sub-irrigation methods, because such soil treatment tends to increase the ravages of potato diseases. Land for potatoes should be in a high state of fertility and deeply plowed. Irrigation should be by the furrow method after the potatoes have been ridged. Small streams of water should be used and great care taken not to over-irrigate. The Colorado Experiment Station has published complete bulletins on potato culture which can be obtained when more detailed information is desired.

FLAX.

Flax does remarkably well on the soils and under the climate of the Valley, but existing freight rates render it inadvisable to grow the crop with the expectation of selling the seed in outside markets as prices are not usually high enough to cover the necessary freight charges and leave a profit to the grower. Flax is an excellent crop to use sometimes as a supplementary feed for livestock. For dairy and pure bred herds especially, a small amount of ground flax added to the rations will give tone and quality to the animals. For such purposes it is sometimes advisable to grow flax. For a cash crop prices usually make it unprofitable.

Land for flax should be prepared as for the small grains. It should be seeded very early in the spring, preferably in April, twenty to twenty-five pounds of seed being used per acre. Flax is subject to a disease known as flax wilt. To reduce the dangers of this disease to a minimum, all seed should be severely fanned to blow out all light seeds. The remaining heavy seeds should be treated with formaldehyde so as to kill all of the wilt spores adhering to the seed.

Irrigation.—Flax does not require heavy irrigation, but it should be kept growing continuously with light or moderate applications of water. The last irrigation should be given not later than the beginning of the blooming period. Late applications of water tend to keep the crop green, thus preventing proper filling and maturing of the seed.

Harvesting.—Flax may be harvested with a binder in the same manner as small grain. The bundles should then either be shocked or allowed to dry until cured. In many seasons flax can be harvested best with a self-rake or an ordinary mower having bunching attachments. When the straw is thoroly dry, it may be stacked or thrashed with a common grain thrasher.

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SWEET CLOVER.

Sweet clover has usually been looked upon as a noxious weed. Stockmen and farmers are finding, however, that under proper conditions it is capable of making nutritious pasture or valuable hay. During the past three years the acreage in sweet clover has been greatly extended thruout the Valley, the discovery that it was valuable for feed coupled with the fact that the crop would grow on many of the alkali or partially seeped lands which would not produce other crops, has assisted in its wide distribution.

The two varieties of sweet clover are distinguished by their yellow and white flowers. For Valley conditions the yellow flowered variety is to be preferred because it is the earlier maturing, and will produce good crops of seed as well as hay. Sweet clover seed is almost exactly the same size and very similar in shape to alfalfa seed.

Land for sweet clover should be prepared the same as for alfalfa. The seeding can preferably be done in the spring by exactly the same methods as those used for alfalfa seeding. Eight to fifteen pounds of the hulled seed is sufficient. If the unhulled seed is used, twenty to twenty-five pounds must be planted to produce approximately the same stands.

Irrigation should be the same as for alfalfa. When intended for hay, sweet clover should be cut before the stems have become unduly woody. To accomplish this it is usually wise to cut when the crown shoots for the next crop appear. The first cutting after seeding should be made with the cutter bar of the mower set rather high, and may be begun when the first bloom appears. It is usually unsafe to cut earlier than this, as earlier cutting may result in killing the crop and necessitate reseeding. Methods of hay-making are the same as for alfalfa.

Probably no crop will prove more beneficial as a soil improver than sweet clover. In the short seasons of the Valley it is probably destined to considerably wider use than it now enjoys, both for hay and for pasture.

RODENTS.

Rodents such as prairie dogs and kangaroo rats do an enormous amount of damage to new lands as well as old lands which have uncultivated sections lying adjacent. The damage is two-fold. Prairie dogs and kangaroo rats dig deep holes in the fields, increasing the difficulties of irrigation and sometimes starting very severe soil washing. Unless their numbers are kept down they are also very destructive to crops. In some places it is almost impossible to start any of the garden crops or alfalfa because of the depredations

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of these rodents. Frequently they will cut off the roots a few inches below the surface of growing alfalfa, thus killing the crop out so that it has to be reseeded.

These rodents can be destroyed if sufficient effort be made, or with less effort they can be so reduced in numbers that injurious effects from their activities will be relatively light. Probably poisoning is the cheapest means for disposing of them. To be effective, the poisoning must be done in the spring before green growth starts, as the prairie dogs and kangaroo rats will eat poisoned grain at this time, but will not touch it after green things become abundant. The State Entomologist and his assistant have worked out successful methods of poisoning these rodents, and will furnish methods of making up the poison upon request. Poisoned wheat will be sold at practically the cost of preparing it.

A recently devised method of killing off these small animals is by the use of dynamite. When this method is used, a piece of dynamite about an inch long is attached to a fuse long enough to let the dynamite well down into the hole. The dynamite is then lowered into the hole and earth is securely patted around the fuse so as to hold it firmly and stop up the hole at the same time. The fuse is then lighted. The dynamite burns without explosion, giving off poisonous gases which quite effectually kill any animals in the burrow. Most of the dynamite salesmen will supply printed directions for this method of exterminating rodents.

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Bulletin 210 October 1915

The Agricultural Experiment Station

OF THE

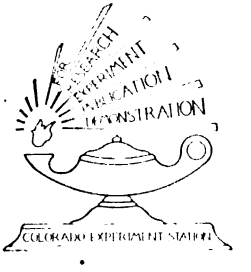
Colorado Agricultural College

INSECTS AND INSECTICIDES

Being a Revised Edition of Bulletin 114

—BY—

C. P. GILLETTE and GEO. M. LIST



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INSECTS AND INSECTICIDES

By C. P. GILLETTE and GEO. M. LIST

INTRODUCTION

The purpose of this bulletin is to furnish brief information regarding the insects that are most frequently found doing destructive work on small fruits, orchards, shade trees and shrubs of this State.

The aim has been to give a concise description of the insects and the treatments that have been found to be most successful in controlling them. The arrangement is not according to the scientific classification of the insects, but according to their host plants.

Part Two, on The Preparation and Use of Insecticides has been made as brief as possible and only the formulae that are in accordance with the best practice are given. Throughout the first part, the insecticides are referred to by number, for sake of brevity.

If you are in doubt as to the pest that is annoying you, feel free to write the Experiment Station and send specimens for identification. Place the insects in a box, along with some of their food, and then write us what information you can as to their work and habits.

PART I.

INSECTS INJURIOUS TO TREES, SHRUBS AND SMALL FRUITS.

APPLE AND PEAR

Fruit

Codling Moth.—This insect probably does more damage to the apples and pears of the State than all other insects combined. Most orchard men are very familiar with the flesh-colored larva that eats into the apple and causes the wormy fruit, but few are familiar with the moth that lays the egg from which this larva hatches. It is a small grayish-brown moth resembling the color of the apple bark and has a wing expansion of from one-half to three-fourths of an inch. It flies mostly in the twilight and is not attracted by light. It flies with a zig-zag motion and does not remain long on the wing.

The larvae pass the winter in tough silken cocoons under the rough bark, in crotches of the trees, in cellars and packing houses, in fruit boxes, and in rubbish on the ground. The moths begin to emerge as the blossoms fall from the trees, and soon begin to lay their eggs upon the upper surface of the leaves near the small fruit. Later in the season, when the fruit is larger and the fuzz has been rubbed off, many eggs are placed directly upon the fruit. Our records show that about 65 percent of the little larvae of the first

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brood, and 40 to 50 percent of the second enter the calyx as soon as they hatch from the eggs. The larvae feed in the fruit for about 21 days, then crawl down the tree to hide while they pupate and change to moths. There are two broods a year in Colorado. It takes about 50 days for one complete generation to develop from egg to egg or moth to moth. See Plate 1.

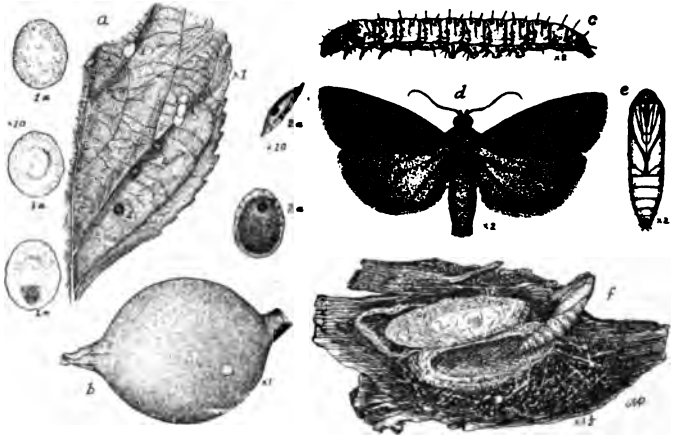

PLATE 1.—Codling Moth in its different stages: a, eggs upon a leaf; a 1, eggs natural size, 1 a, eggs much enlarged; upper 1 a, a newly laid egg; middle 1 a, the appearance of the egg after 4 or 5 days showing the flesh-colored ring of the embryo; lower 1 a, showing the outline of the small larva, the dark spot being the head (an egg in this stage woud hatch in a day or two); a 2, eggs parasitized by Trichogramma minutus, a very small 4-winged fly that deposits its eggs within those of the codling moth; 2,a, parasitized codling moth eggs much enlarged, showing holes made by the parasites as they leave the eggs; upper 2 a, side view of parasitized egg; b, egg natural size upon an apple; c, codling moth larva; d, codling moth; e, chrysalis of puna; f, cocoon and chrysalis. Figures a1 and a2 and b, natural size; 1 a and 2 a, enlarged 10 times; c, d, and e, enlarged 2 times; f, enlarged 1½ times, Original, Miriam A. Palmer, Delineator.

Remedies.—Remedies 2, 4, 5, and 29 are used against this pest. The arsenical poisons are most effective, and of these arsenate of lead is most generally used, in the proportion of 3 to 4 pounds of the paste to each 100 gallons of water. As a large percent of the little worms enter the calyx of the fruit, it will readily be seen that careful attention should be given toward destroying these. The sole purpose of the first spray is to get poison into the calyx cups that these little worms will be poisoned as they try to enter the apple. This spray should be applied just after the blossoms fall, and before the calyx lobes close. There are only a few days when the fruit is in the proper condition to receive this spray. Continue the application until every calyx is filled with the liquid. Large trees will require from 8 to 16 gallons for a thorough treatment. See Figs. 1 and 2.

Much has been written in regard to the so-called one-spray method of controling the codling moth. It consists in putting on this first spray very thoroughly. This seems to be sufficient in

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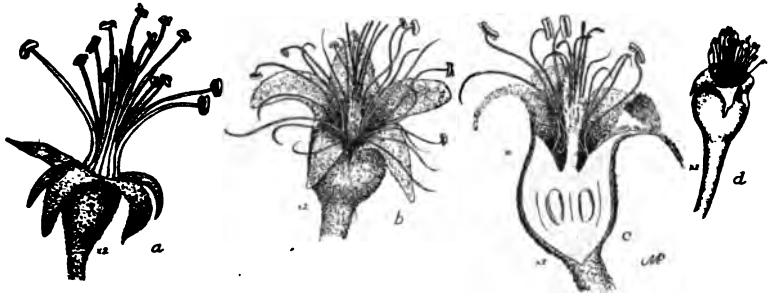

Fig. 1.—a, small apple from which the petals have just fallen. Effective spraying for the codling moth may be done in this stage but it is not in as good condition for receiving the spray as b; b, small apple in the proper condition to receive the first spray for codling moth. The calyx-lobes have begun to close and form somewhat of a cup for holding the liquid and the stamens have begun to dry and will allow the liquid to enter the inner part of the calyx cup; c, cross section of b, showing the calyx cup, all parts of which must be covered with the spray to effectively poison the worms; d, pear in condition to receive the spray. Original. Miriam A. Palmer, Delineator.

some sections of the country, but in most parts of this State, where the second brood is several times as large as the first, it will usually bring disappointing results. By this method, it is possible to poison the 65 percent that enter the calyx, but it gives little or no protection against the remaining 35 percent that enter the side of the fruit.

Fig. 2.—Blossoms from which the petals have fallen and still in good condition to receive the spray. The calyces of the two larger ones have closed. It is too late to effectively apply the calyx spray to them.

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The second spray should be applied as soon as the eggs begin to hatch, and the larvae to enter the fruit. This will be about three weeks after the first spray is applied. The hatching of the first brood eggs continues over a considerable period of time, and most growers find that it pays to direct still another application against them. This should follow about two weeks after the other spray.

If the orchard has been badly infested, or is near one that is badly infested, it will pay to spray for the second brood. If a second brood spray is applied, it should follow about nine weeks after the first. If the worms are numerous, another treatment may be made in two weeks. All sprays after the first are to cover the surface of the fruit with poison.

Remedy No. 29, that of using bands, is a great help in keeping this pest under control.

Fruit-Tree Leaf Roller.—This pest often blemishes and even destroys much fruit early in the season. The little larvae begin to feed freely about the time the apples begin to form. Entire clusters of fruit may be destroyed then, or be so blemished that they will be of no value. See Plate 2.

For remedies, see under Foliage.

Green Fruit Worm.—This is a large green caterpillar with a narrow cream-colored stripe down the middle of the back, and a wide but less distinct line down each side. When fully grown, the larvae are from one to one and a half inches long. There is but one brood in a season. The moths appear in the spring and lay their eggs upon the fruit trees. The larvae hatch out and feed upon the leaves and fruit. The blemished fruit will often remain on the tree until picking time, but will show the scars. This worm feeds upon most of the tree fruits, but is most often found on the apple and pear. It feeds during May and early June.

Remedies.—The fruit worm very seldom gets numerous enough to demand attention. Spraying for the codling moth aids in keeping it in check. Any of the arsenicals will be found effective if applied while the larva is small.

Plum Curculio.—The plum curculio often does serious damage to apples, and will attack pears, but is not as serious on these as on stone fruits. The damage comes from the feeding and egg-laying punctures. This insect has never been reported in Colorado. For description and remedies see under Plum.

Apple Curculio.—This is very similar to the plum curculio and is often taken for it. It is a reddish brown snout-beetle about one-quarter inch in length with a snout or beak one-half as long as the body. It

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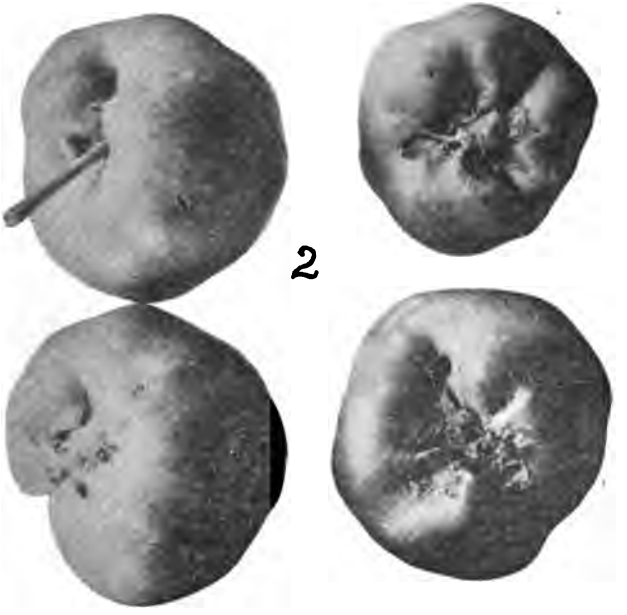

PLATE 2.

Fig. 1.—Apples picked on June 8, when they were from five-eighths to three-quarters of an inch in diameter, showing the characteristic injury from leaf-roller; figure 2, apples picked from same orchard on August 9, when they were about two inches in diameter. Original in Circular 5, Office of State Entomologist.

can be distisguished from the plum curculio by being smaller and having two humps on each wing cover, while the plum curculio has only one. The beetles hibernate under grass, or any rubbish about the orchard, and appear on the trees about the time the petals fall, and begin to feed upon the young apples. The females begin laying eggs in the apples when the later are about one-quarter inch in diameter. A puncture is made with the beak, the pulp eaten out and the egg de-

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posited in the cavity. The food punctures are similar to those made by the plum curculio. The cells about the punctures are destroyed, the growth stops and a deformed apple is the result. The female seals the egg punctures with excrement and does not cut a crescent-shaped mark about them, as does the plum curculio. There is but one brood a season.

Spraying with arsenicals will destroy a few of the curculios, but best results are obtained by destroying all hibernating places and cultivating the soil. They are always worse in thick, unpruned and uncultivated orchards.

San Jose Scale.—If an apple or pear tree is infested with this pest the fruit is very likely to show scarlet blotches about one-eighth of an inch in diameter, in the center of each of which will be found one of

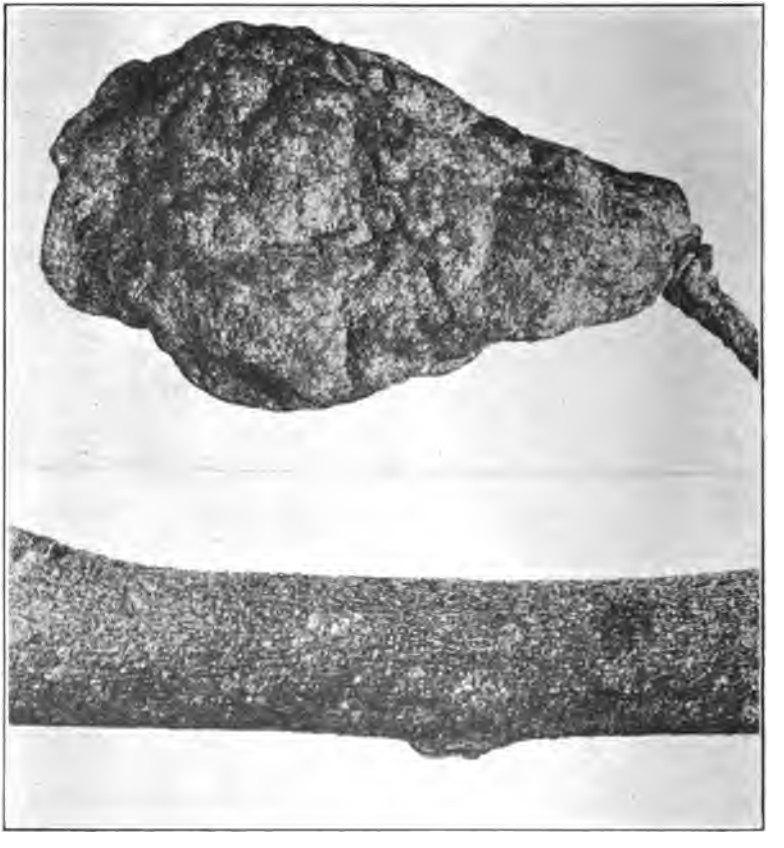

Fig. 3.—The San Jose scale on pear and willow. Note the roughened surface of the pear. Natural size. (After O. E. Essig, "Injurious and Beneficial Insects of Calif." Calif. State Com. of Hort.

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the scale insects. This is one of the best means of detecting an infestation in an orchard. On pears it will make more or less of a depression, but without the scarlet color being so pronounced. For remedies see under Bark and Wood. See Figs. 3 and 4.

Putnam Scale.—This is occasionally found on fruit. See under Bark and Wood.

Howard Scale.—The Howard scale quite often attacks apples and pears. It is often difficult to distinguish this from the San Jose scale. The scarlet color on the fruit shows to some extent but is not as characteristic as with the San Jose scale. On pears the depressions under the scales are usually well marked. See Plate 3. See Bark and Wood for remedies.

Fig. 4.—San Jose Scale on apples. Note the characteristic reddish blotches around the scales. Reduced (After Britton.)

FOLIAGE

Fruit-Tree Leaf-Roller.—This has been a serious pest in one or two sections of the State where entire orchards have been largely defoliated. It feeds upon all of our fruit trees, with the exception of the peach, and upon many shade trees. It passes the winter in the egg stage. The eggs are deposited upon the twigs and the bark of the trees in masses varying from 25 to 100 or more. The female covers the eggs with an impervious gummy substance, which protects them and gives them a brown or gravish color. They begin to hatch as the buds begin to open and the little worms enter the buds and tie the leaves together with webs. As the leaves grow they roll up forming

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a nest in which the caterpillars feed. The larvæ eat fruit as well as leaves if any should be enclosed within their nest. As the leaves get larger often a single leaf will be rolled to form a nest.

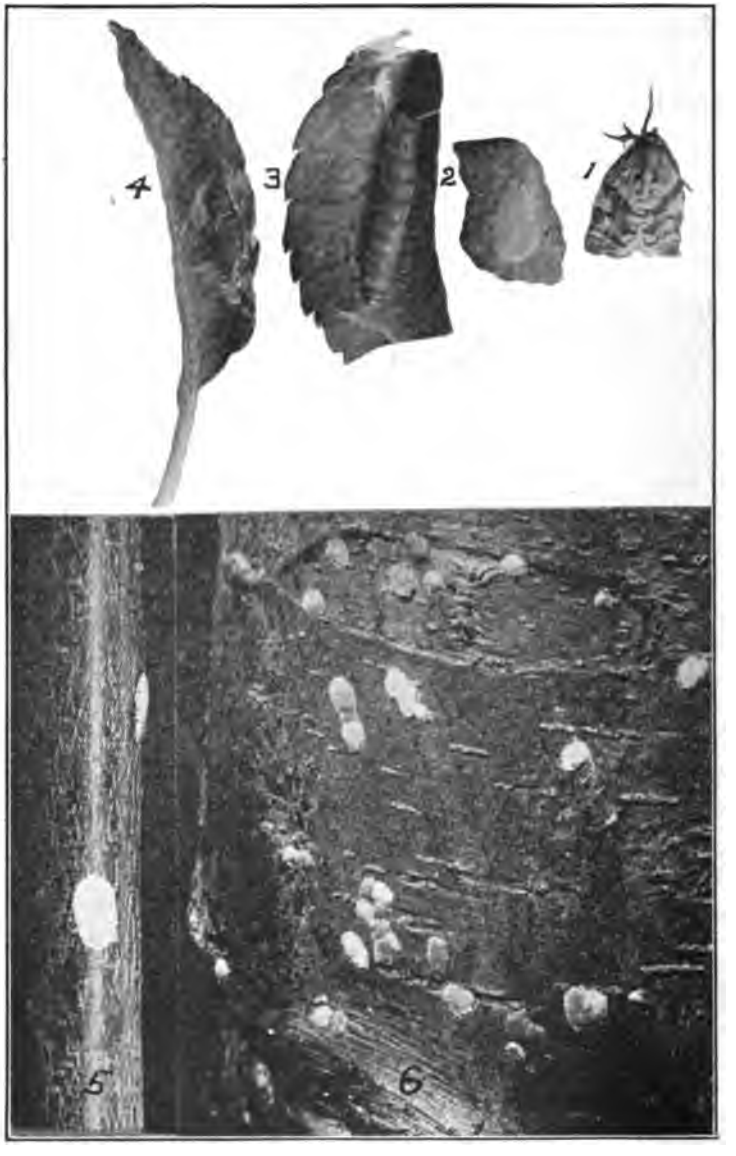

PLATE 4.— Fig. 1.—Adult leaf-roller moth; figure 2, hatched egg mass on bark; figure 3, adult larva; figure 4 pupa; figure 5, light-colored egg masses on bark; figure 6, thirty-five hatched egg masses in a space of twelve square inches. Original in Circular 5, Office of State Entomologist.

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The larvæ feed for about four weeks. When mature they are light green in color, with brown or black head and legs, and they are very active if disturbed.

Pupation takes place within the nest, only a very delicate cocoon being made. The moths emerge in about ten to fourteen days and soon begin laying eggs. There is but one brood a year. See Plate 4.

Remedies.—Best results have been secured by a thorough application of miscible oil, one part in nineteen parts of water, made early in the spring before the eggs begin to hatch. Kerosene emulsion failed to give the same results.

Many of the young caterpillars can be killed by the use of arsenate of lead, 5 or 6 pounds of paste in 100 gallons of water. Make the first application just as the buds begin to burst, and the second just as the cluster buds begin to separate. The regular codling moth spray, just after the petals have fallen, should follow.

San Jose Scale.—See Bark and Wood.

Putnam Scale.—See Bark and Wood.

Tent Caterpillar.—This insects passes the winter in the egg stage and hatches as the buds begin to open. The worms make nests in the forks of branches, in which they remain when not feeding. The eggs are placed in clusters of from 100 to 200 on the small branches and are covered with a cement-like substance. See Fig. 5.

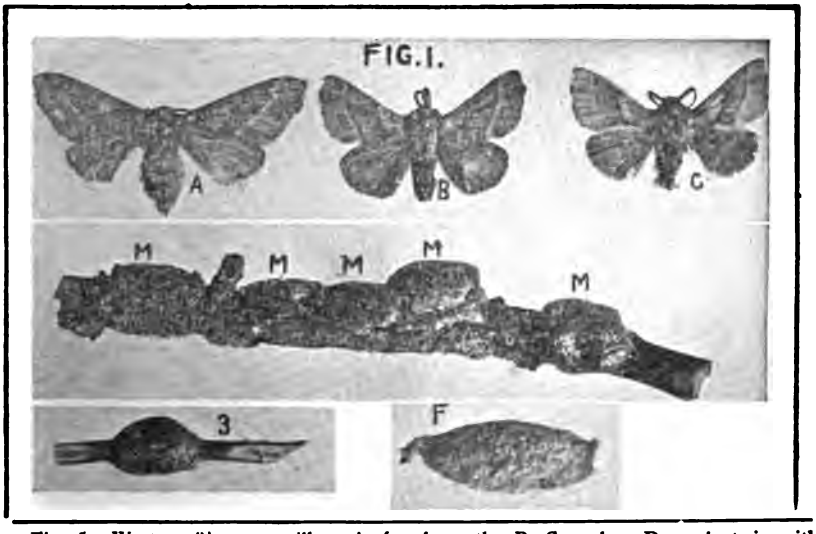

Fig. 5.—Western Tent-caterpillar; A, female moth; B, C, males; D, apple twig with egg masses (M). F, cocoon. 3, egg-mass of American Tent-caterpillar. Life size,

Remedies.—The worms are usually kept under control in orchards that are sprayed for the codling moth. Any of the arsenicals will

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destroy the small caterpillars. While pruning, many of the egg masses can be cut off and destroyed. The nests can be burned out with a torch.

Fall Webworm.—The webs do not appear until late in the summer. The insect hibernates in the pupa stage. The moths, which are white, emerge in the late spring and summer when they lay their eggs upon the leaves. The worms enclose within their loose web all the foliage upon which they feed, while the Tent Caterpillar spins a smaller nest to live in when not feeding. See Fig. 6.

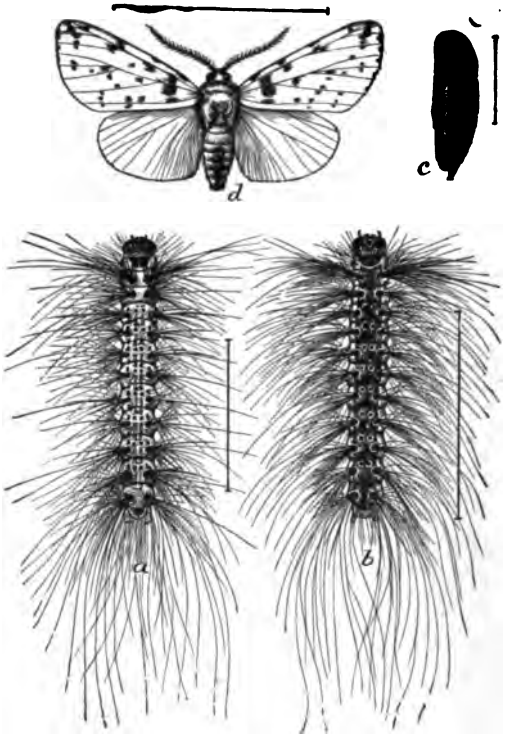

Fig 6.—Fall Web-worm; a and b, caterpillars; c, chrysalis; d, moth. (Howard, Yearbook, U. S. Dept. of Agriculture, 1895.)

Remedies.—Same as for Tent Caterpillars.

Apple Flea-Beetle.—This is a small metalic-green beetle about one-sixth of an inch in length, with hind legs so developed that it can jump like a flea. These beetles sometimes attack young trees or newly budded or grafted nursery stock, and do serious damage by eating holes in the leaves. Very little damage is ever done large trees.

Remedies.—Any of the arsenicals (2-4-5) are quite effective in destroying this pest. Any material that will form a dust over the foli-

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age has a tendency to keep these beetles from feeding. Nos. 6-7-15 and 27 may be used as repellants.

The Apple Leaf-Hopper.—This is a small, active, greenish-yellow insect about one-sixth of an inch in length that feeds upon the leaves of apple and pear, and some other plants, by sucking the juices and giving the leaves a mottled yellowish appearance, often causing them to fall prematurely. The young feed on the under side of the leaves mostly. They do not develop wings until their last moult, but are very active, running in all directions if disturbed. They winter over as eggs deposited in the bark of the small branches.

This insect as a rule does little damage, except occasionally to growing nursery stock, and sometimes it is abundant enough to damage the foliage and speck the fruit with excrement so that it is made unsightly and unsalable.

Remedies.—Must consist of contact sprays applied before the insects develop their wings. Spray from below to strike the hoppers on the under-side of the leaves. Use Nos. 8-9-10-11-12-18-19.

The Green Apple Aphis.—This is a small green louse that feeds on the under-side of the leaves of apples and sometimes the pear and quince, sucking the plant juices and causing the leaves to curl. It is usually worse during the latter part of the season. It winters over in

PLATE 3. Fig. 2.—Young Bartlett Pear, life size, showing both young and adult of Howard scale. The young scales are white.
Fig 3.—Two apple twigs showing eggs of the green apple aphis; between these twigs two needles of pine showing eggs of another species of aphis that works upon the pine. Original in Fourteenth Annual Report, Colorado Experiment Station.

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the egg stage. The eggs are small, black, shiny objects placed upon the small twigs of the trees. See Plate 3.

Remedies.—It is very difficult to destroy the eggs. The sprays usually recommended for this purpose cannot be depended upon. The best treatments consist in spraying with tobacco extract (19), kerosene emulsion (10), or soap (8), after the eggs have hatched, and before the leaves begin to curl.

Rosy Apple Aphis.—This aphis or louse gets its name from its rosy or pinkish color. It is quite a serious pest to the apple in some sections, but has been found in Colorado in only two or three localities in sufficient numbers to do serious damage, The small, black, shiny eggs hatch in the spring about as the buds begin to open. The lice feed upon the leaves and twigs much as the Green Apple Aphis does, but they seem to have a poisoning effect on the twigs and fruit. leaving the twigs crooked and stunted and the fruit small and knotty. This pest remains on the apple and pear only a part of the season leaving the latter part of June for another food plant. It returns in the fall to deposit its eggs upon the apple and pear. See Fig. 7.

Remedies.—Same as for Green Apple Aphis.

Fig. 7.—Apples disfigured by the attacks of the rosy apple aphis when the fruit was young. These were picked at harvest time. Reduced one-half. After O. E. Essig, Bul. "Injurious and Beneficial Insects of Calif." Calif. State Com. of Hort.

Grasshoppers.—Grasshoppers do serious damage to young orchards, especially when they are sown to some crop that will not permit of an

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annual cultivation to destroy the eggs, or when the orchard is adjoining an alfalfa or grass field. They can be held in check somewhat by the arsenical sprays (2-4-5). The best results in poisoning them are secured with poison bran-mash (3). A band of sticky material (31) about the trees will keep the wingless ones from climbing. See Fig. 8.

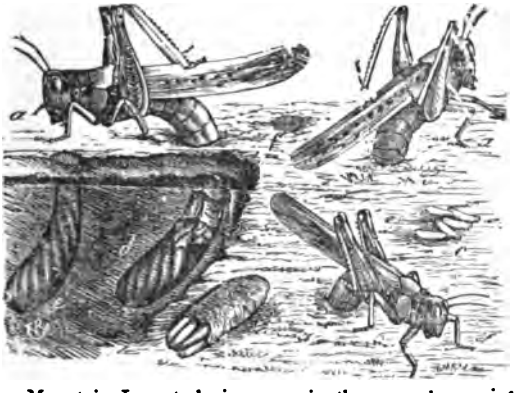

Fig. 8.—Rocky Mountain Locust, laying eggs in the ground; a, a, females with their abdomens in the ground; b, an egg-pod broken open; c, scattered eggs; d, egg-packet in the ground. (After Riley.)

The hoppers can be kept from migrating from alfalfa and grass fields by the free use of hopper-dozers or pans (30). See Plate 5.

Brown Mite or Clover Mite.—This is a very small brown or reddish mite. It feeds upon a large range of plants, including practically all of our fruits. It takes the name of Clover Mite from the clovers on which it is often very numerous. The dry climate of Colorado is very favorable to its increase. It feeds chiefly upon the leaves. Its presence is most easily detected by the faded, sickly appearance of the foliage of the trees. See Plate 6.

This pest winters over in both the egg and the adult stages, the small red eggs being placed upon the bark of the trunk and limbs and especially in the crotches of the smaller limbs. When very abundant the eggs color the bark red. Sometimes in the fall this mite becomes an annoyance by leaving the food plants and entering our dwellings. It does not bite people.

Remedies.—The use of lime and sulphur (16-17) early in the spring to destroy the eggs or the mites as they hatch is probably the best means of control. Kerosene emulsion (10) and Soluble Oil (12) are also quite effective at this time.

To kill the mites during the summer, use sulphur (20) at the rate of one pound to three gallons of water, with a small amount of soap about two pounds, to 100 gallons. Contact sprays (8-10-12-19) will destroy the mites, but a second application is required to kill those

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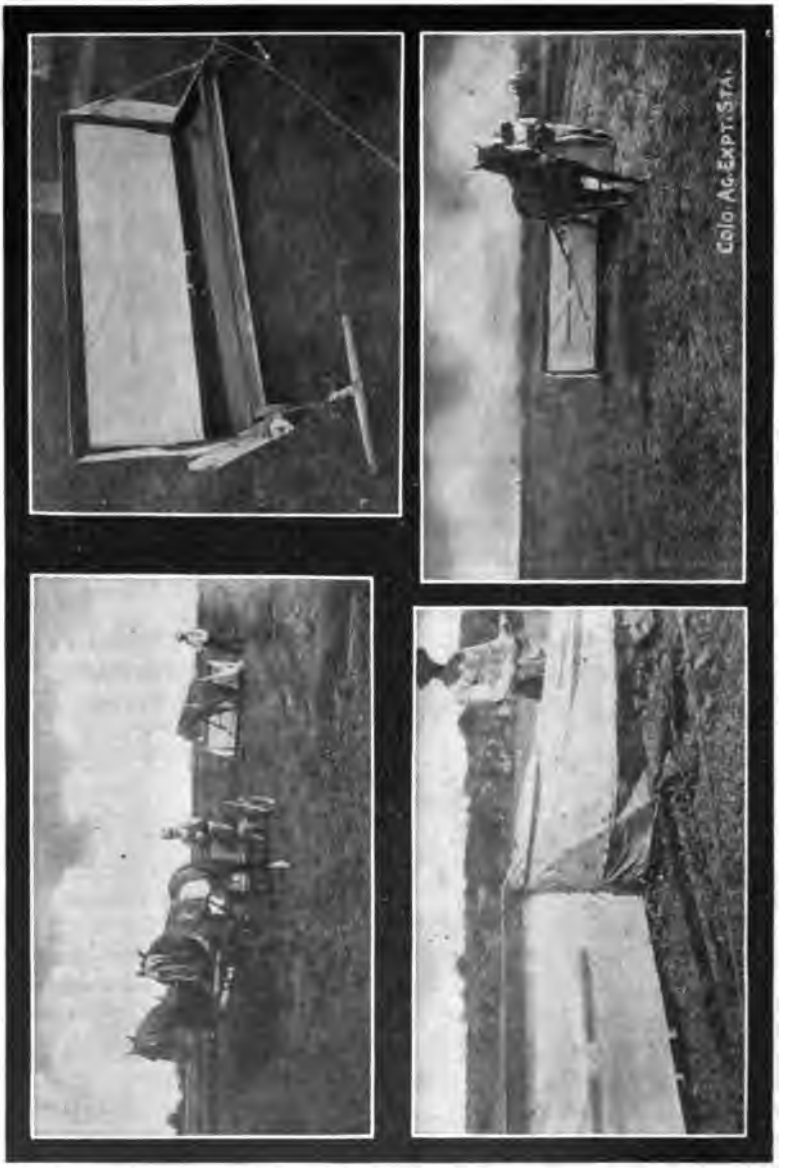

PLATE 5.—Home-made Hopper-dozer, after Blinn. Manner of hitching horse
Near view, showing pan Hopper-dozer
Following the mower

that hatch from eggs. Sulphur usually remains on the tree long enough to destroy any that hatch from eggs after the treatment.

The spraying should be done from below, as the mites work largely on the underside of the leaves.

The Red Spider.—The Red Spider is very similar to the brown mite, the adult being somewhat smaller and greenish or reddish in

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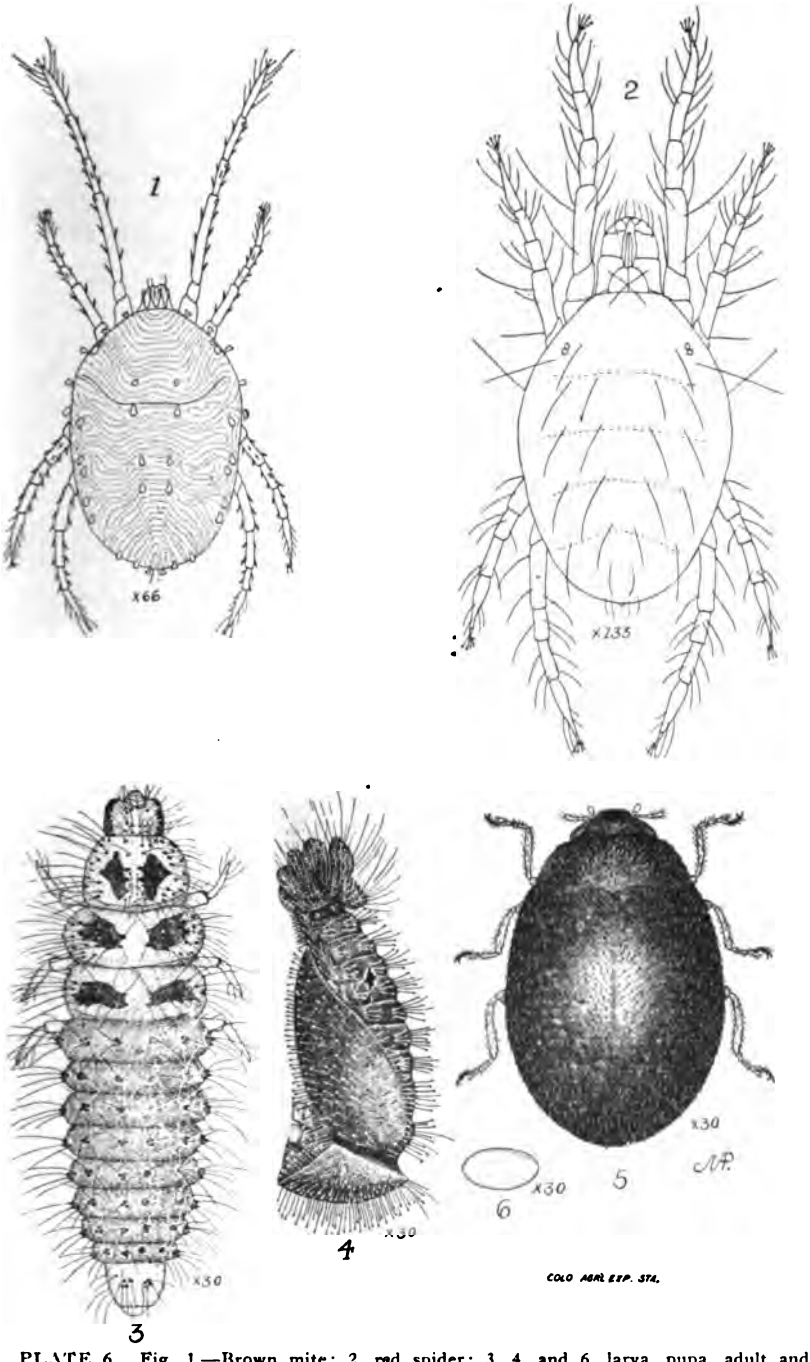

PLATE 6. Fig. 1.—Brown mite; 2, red spider; 3, 4, and 6, larva, pupa, adult and egg of (Scymnus punctum); a small lady-beetle that feeds upon the brown mite and red spider. Fig. 1 enlarged 66 times; 2 enlarged 133 times; 4, 5, and 6 enlarged 30 times. Original in Bull. 152, Colo. Exp. Sta.

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color, and always works under a slight web which it spins. The work of the two are often confused, but they vary a great deal in their life histories. The young red spider winters over under the bark of trees and rubbish on the ground. The spiders are best distinguished from the brown mites by the fine web they spin over the surface of the leaves. The young resemble the adults but are lighter in color. See Plate 6.

Remedies.—The remedies recommended for summer use against the brown mite will control the spider also. In cities where a strong current of water is available, both the mites and spiders may be controlled by frequently washing them from from plants and trees.

Pear Slug.—See under Cherry.

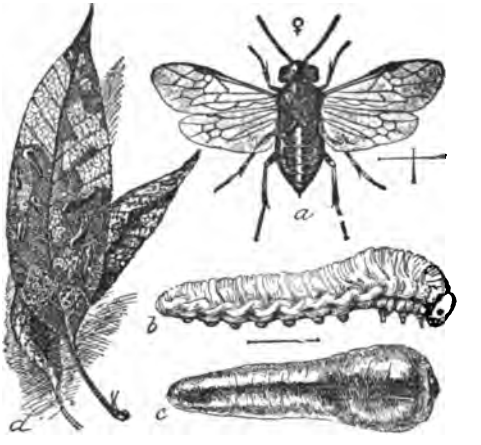

Fig. 9.—Pear-tree Slug; a, adult fly; b, larva or slug with slimy covering removed; c, same as preceding in natural condition; d, leaves showing slugs and their injuries. (Marlatt, Circular 26, Second Series, U. S. Dep. of Agr., Div. Entomology.)

Pear Leaf-Blister Mite.—This is a very small mite that lives within the tissue of pear leaves, and in some cases apple leaves, causing small reddish or brownish blisters. When numerous these may involve the greater portion of the leaves causing them to fall prematurely.

The mites pass the winter under the bud scales on the trees.

Remedies.—Spray while the trees are dormant, with lime and sulphur (16-17) kerosene emulsion (10), or Soulble Oil (12).

Vagabond or Rust-Mite of the Pear.—This mite is quite similar to the preceding in size and appearance, but feeds entirely upon the surface of the leaves and tender bark of the new shoots, causing a rusty appearance and a dwarfing of the foliage. In severe cases the leaves curl and the foliage seems scanty. See Fig. 10.

Remedies.—Same as for the preceeding species.

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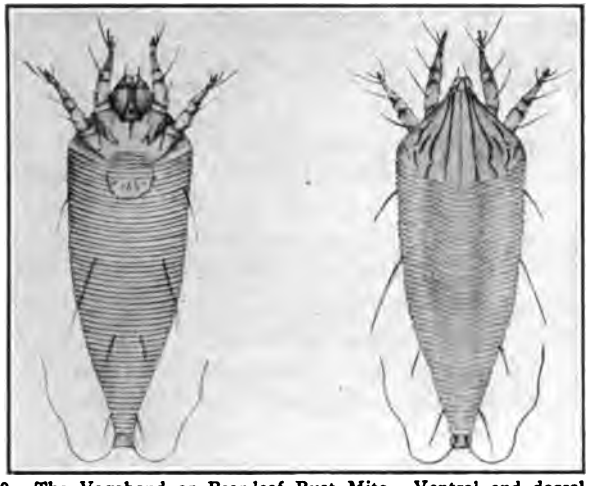

Fig. 10.—The Vagabond or Pear-leaf Rust Mite. Ventral and dorsal views. Greatly enlarged. (After Malepa from Parrott.)

BARK AND WOOD

San Jose Scale.—This is one of the most dreaded insects to all orchardists. It is responsible for the death of thousands of fruit trees in many sections of the country each year. The great danger comes from the rapidity with which it multiplies, and the difficulty the inexperienced orchardist has in locating the infestations. It may be present in sufficient numbers to kill the trees before its presence is discovered. It attacks practically all decidious fruits and ornamental plants, infesting all parts of trees including trunk, branches, leaves and fruit, often getting so abundant on the branches as to encrust them with scales, giving them a gray, ashy, dead appearance. See Fig. 3.

The scale is a waxy secretion which, together with the old cast skins of the insect, acts as a protection to the soft yellow insect beneath it. The full grown females are covered by a circular scale about one-sixteenth of an inch in diameter with a central dark nipple. The scale of the male is smaller, gray in color, and oval, with the nipple nearer to one end.

The small, half-grown female scales are dark in color, almost black, and circular. This characteristic is used to distinguish this scale from the Putnam and Howard scales, and other closely related species.

When upon fruit the San Jose Scale makes a red or scarlet blotch that is quite characteristic. During fruit harvest is one of the best times to detect infestations. This same red discoloration is found within the outer bark surrounding the feeding place of the insect. See Figs. 3 and 4.

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If trees are found to be infested, immediate action should be taken. Small trees may be killed in one or two seasons and older trees so weakened that they are of little value. This scale has been discovered in one fruit growing section of Colorado, and may break out in others at any time. Anyone finding scale insects that he can not identify should send them to the Experiment Station for identification.

Remedies.—Spray with lime and sulphur mixture (16-17) while trees are dormant. The soluble or miscible oils (12) are also quite effective. It is usually best to cut and burn badly infested trees.

Putnam Scale.—This very closely resembles the preceding species. Mature scales are slightly larger and lighter in color and the central spot on the scale is reddish and somewhat to one side of the center. Remedies the same as for the preceding.

Howard Scale.—This scale is very difficult to distinguish, in external appearance, from the preceding species. It is about the same size and has a pale gray color, with a dark orange colored nipple somewhat to one side of the center.

This species is pretty generally scattered over the State. It does most damage to the pear, plum and prune, but also infests apple, peach, ash and maple. It causes a peculiar pitting of the surface of pears. It

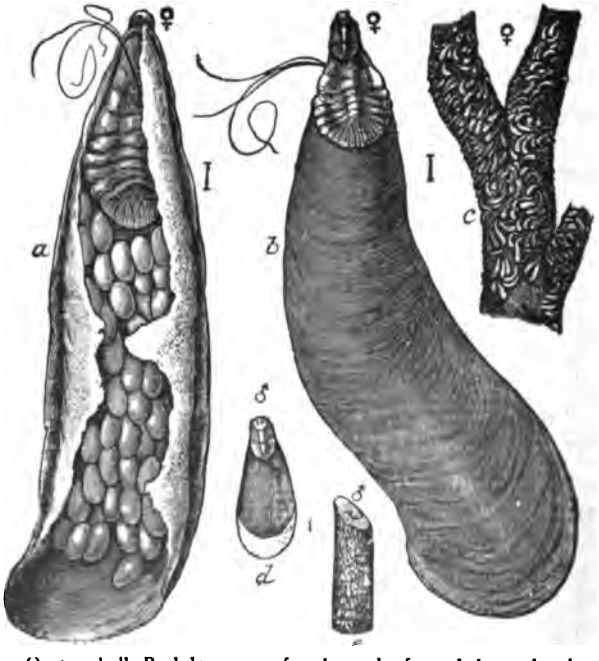

Fig. 11.—Oyster-shell Bark-louse: a, female scale from below, showing eggs, greatly enlarged; b, the same from above; c, female scale on twig, natural size; d, male scale enlarged. Howard, Yearbook, U. S. Dep. of Agr., 1894.

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also makes the scarlet blotches on fruit and bark somewhat similar to the San Jose scale, but does not increase as rapidly. See Plate 3.

Remedies.—Same as for San Jose Scale.

Oyster-Shell Scale or Bark Louse.—This is an elongated oyster-shell shaped scale of about the same color as the bark of the trees. It infests especially lilac and apple and pear trees. It passes the winter in the egg stage under the old scale. See Fig. 11.

Remedies.—Dormant sprays are ineffective. Black leaf 40 (19), 1 part to 800 parts water, or kerosene emulsion (10), 8% kerosene, applied in the spring when eggs are hatching, will kill the young lice.

Scurvy Scale.—This is a white scale insect. The female is about one-eighth of an inch long, flatter and more circular than the oyster-shell scale, and gives the bark a scurvy appearance. Male scales are much smaller and very slender. Like the Oyster-shell scale, it passes the winter in the egg stage under the old scales. When eggs are crushed they are of a deep purple color.

Remedies.—Same as for Oyster-shell scale.

Woolly Aphis.—Small reddish-brown lice attacking trunk and branches of the apple, especially on tender bark about wounds and on water-sprouts. They appear as bluish-white woolly patches which, when crushed, give a dark blood-red stain. The lice are covered with a woolly mass of white secretion. They suck sap from the bark and often cause an abnormal growth or swelling where they feed. See Fig. 12.

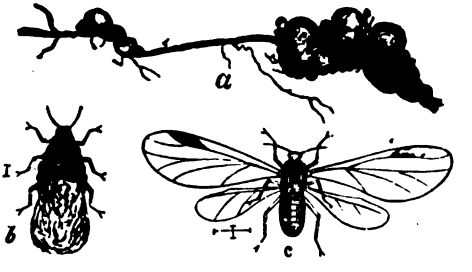

Fig. 12.—Woolly Aphis, root form: a, small root showing swellings caused by the lice; b, wingless louse showing woolly secretion; c, winged louse. (After Saunders.)

Remedies.—The white patches on the trunk and branches may be painted out with pure kerosene or crude petroleum (11), kerosene emulsion (10), or tobacco extract (19).

If the lice become abundant on branches and twigs, spray with "Black Leaf 40," 1 part to 800 parts water, with 3 pounds of soap to each 100 gallons to aid in penetrating the wooly secretion; or use kerosene emulsion (10) ordinary strength. Use a high pressure and coarse spray, in order to wet through the wool.

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Flat-Headed Borer.—A light-yellow legless grub that bores beneath the bark of apple and many of our shade and forest trees. The first body segments are flattened, making the larvæ appear to have an enlarged flat head. The adult is a dark brown metalic colored beetle about three-fifths of an inch long. This insect very seldom attacks any but weakened or injured trees. See Fig. 13.

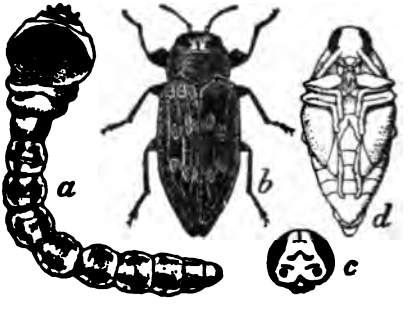

Fig. 13.—Flat headed Apple-tree Borer; a, flat-headed larvae; b, the mature beetle; c, head of mature beetle; d, pupa. All twice natural size. (Chittenden, Circular 32, U. S. Dep. of Agr., Div. of Entomology.)

Remedies.—Keep trees in thrifty condition. Protect from sun scald during winter and spring by shading or white-washing (15). Remove borers with pocket-knife when found.

Grasshoppers.—Grasshoppers sometimes eat bark from trees in the nursery rows or in young orchards.

Remedies.—See under Foliage.

PEACH, PLUM, PRUNE, APRICOT AND CHERRY

FRUIT

Twig-Borer of Peach.—The small brown larvæ of this insect winter over in silk-lined cavities made in the bark, especially in the crotches of small limbs. These are detected by a small mass of chewed bark which covers the burrows. Early in the spring the larvae leave the burrows and eat into the buds and new shoots causing them to wilt and die. The same larva may eat into several twigs, thus a few can do serious damage, especially to small trees. See Figs. 14 and 15.

Many of the second brood larvae eat into the peaches, causing a gummy exudation and ruining them for the market. This is probably the worst insect pest of the peach in Colorado at the present time.

Remedies.—Lime and sulphur mixture (16-17) has been most generally used in this State. Spray just before the buds begin to open. At this time the larvæ begin to leave their winter quarters and are most

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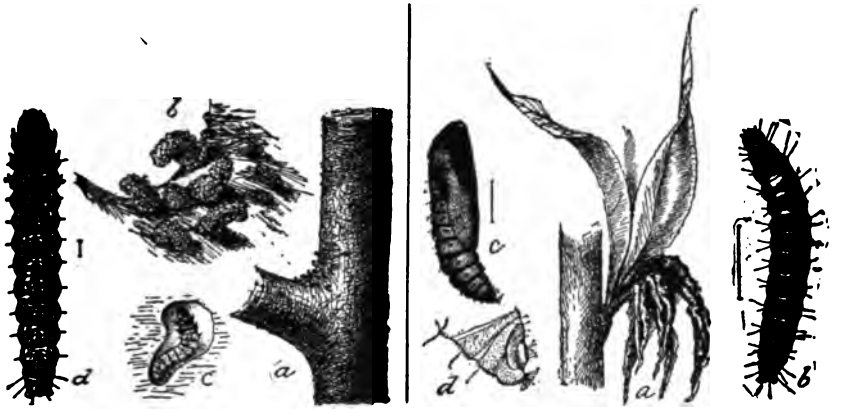

Fig. 14.—Peach Twig-borer; a, twig of peach showing little masses of chewed bark above the larval burrows; b, the same enlarged; c, larva in winter burrow, enlarged; d, hibernating larva greatly enlarged. (Marlatt, Bulletin 10, N. S. U. S. Dept. of Agr., Div. of Entomology.)

Fig. 15.—Peach Twig and Borer; a, young shoot wilting from attack of borer; b, adult larva enlarged; c, chrysalis enlarged; d, tail end of chrysalis showing hooks. (Marlatt, Bulletin 10, N. S., U. S. Dep. of Agr., Div. of Entomology.

easily killed. Winter applications are of very little value in our experience.

Kerosene emulsion (10) and soluble oils (12) may be used, but are thought not to be quite as effective, and are more likely to cause injury.

Fig. 16.—Plums, life-size, showing the punctures and gummy exudations caused by the plum gouger. The black specks on the plums represent the punctures which are made either for the purpose of taking food or egg-laying. Original in Fourteenth Annual Report Colo. Exp. Sta.

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If spraying for the twig-borers alone, arsenate of lead (4) used just after the buds open, gives good results. Many growers prefer this to the lime sulphur treatment. Destroying infested fruit and twigs before the larvæ leave them aids in keeping this pest in check.

Plum Gouger.—This pest feeds upon plums, prunes and nectarines. It is a small gray snout beetle, a quarter of an inch in length, with ocher-yellow head and legs, wing covers smooth and without humps which are characteristic of many snout beetles. The beetles feed upon the fruit, making small punctures in the skin. Eggs are deposited in some of the punctures and the grub eats into the pit, destroying the seed. The larva pupates within the seed, the adult coming out about the time the fruit matures. The adults winter over in the soil. See Figs. 16 and 17.

This is probably the worst pest of the native or Americana plums in Colorado.

Remedies.—Jar the trees early in the morning and catch the beetles on sheets held beneath. Do this from the time the blossoms are out until no beetles are caught. Spray with arsenate of lead (4) soon after the blossoms fall, and again ten days later.

Plum Curculio.—This beetle is very similar to the preceeding one. It is brown to blackish in color, about one-fifth of an inch in length, and with two prominent humps and several smaller ones on its back.

There are two broods. It winters in the beetle stage in the soil, and in rubbish. The adult comes out in the spring and feeds upon the buds and foliage, and later upon the small fruit.

The food punctures in fruit are similar to those made by the preceding species, but the eggs are deposited in skin punctures that are distinctly crescent-shaped. The larvæ do not enter the pit, but feed

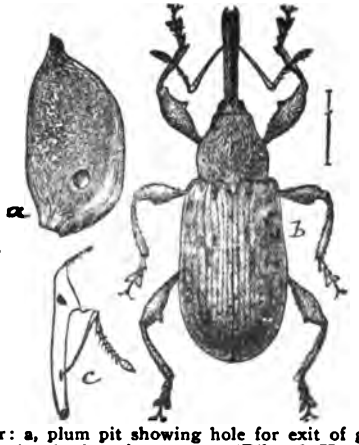

Fig. 17.—Plum Gouger: a, plum pit showing hole for exit of gouger; b, gouger; c, side view of head of gouger showing beak and antenna. (Riley & Howard, Insect Life, Vol. II., U. S. Dep. of Agr., Div. of Entomology.)

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upon the flesh, causing the fruit to fall. The curculio infests plum, peach, cherry, apple. pear, wild plum, and hawthorn. It is to the cherry and plum what the codling-moth is to the apple.

This pest has never been reported in Colorado. Anyone finding what he thinks is its work should notify the Experiment Station.

Remedies.—Same as for preceding species. Spraying with arsenate of lead gives better results than with the plum gouger. Probably the best remedy consists in keeping the orchard free of rubbish and giving a fall cultivation to destroy the over-wintering beetles. The beetle thrives in over-grown, unpruned and neglected orchards. They are shy of the sun. Prune the trees and let the sun in.

Green Peach Aphis (See Foliage).—This plant louse attacks the fruit of the peach and plum just after the flowers fall, causing many of the little fruits to drop.

Tarnish Plant Bug.—For some time there has been considerable complaint from peach growers of the State of waxy peaches. The wax or gum forms in small beads or long strings on the fruit. When brushed off, very little, if any blemish is left. This is often caused by the food punctures of the tarnish plant bug, a small, brownish, and very active plant bug about one-fifth of an inch in length. Early food punctures may cause deformed fruit.

The adults winter over among weeds and rubbish about the orchard, and breed principally on the weeds and under-growth. Occasionally they deposit their long white eggs in the fruit.

The nymphs or young are wingless, attaining their wings at about one month of age.

Remedies.—This is a very difficult insect to control, owing to its wide range of food-plants, and the fact that much of the injury is done by the winged adults which are very shy and active. Numbers 10 and 19 will be found to be of some value. Clean cultivation and the destruction of all hibernating places will also help much.

Scale Insects.—Some of the scale insects, especially the San Jose and Howard scales, will attack the fruit. The Howard scale is quite bad on plums in some sections, spotting the fruit and making it unsalable. (See under Apple and Pear.)

FOLIAGE

Green Peach Aphis.—A pale green or greenish yellow louse that hatches from the over-winter eggs early in the spring. It attacks the blossoms and small fruits, causing many to drop, and later attacks the leaves which curl and turn yellow. About mid-summer this louse

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leaves the peach and goes to a large variety of other plants. It returns to the peach in the fall to deposit the over-winter eggs upon the twigs. This louse also infests the plum.

Remedies.—Spray after the eggs hatch and before the lice get into the opening buds with Black Leaf 40 (19), 1 part to 800 parts water; kerosene emulsion, 5 to 8 percent kerosene; or miscible oils. If the lice appear later, treat as in case of the green apple aphis.

Black Peach Aphis.—This louse, which is amber to black in color, attacks the peach only. It attacks the roots as well as parts above ground. It is on the twigs and foliage only until about mid-summer, but remains on the roots all the year.

Remedies.—For those above ground, treat the same as for green aphis on apple. For the root form, use the same treatment recommended for the root form of the woolly apple aphis.

This has not been a serious pest in Colorado, only an occasional tree having been found infested.

Green Plum and Prune Aphis.—This is commonly known as the hop plant louse, the hop being the summer food-plant. It migrates to the plum and prune in the fall to deposit the over-winter eggs. Winged lice return to the hop early in the summer.

Remedies.—The same as given for the green peach aphis.

Cherry and Pear Slug.—This is a dark-colored, slimy larva much resembling a small snail. The body is large in front and tapers behind. It feeds upon the upper surface of the leaves, often leaving only a skeleton to wither and die. The adult is a small, glossy black four-winged fly about one-fifth of an inch in length. This fly deposits her eggs in the tissue of the leaves just under the epidermis by means of a saw-like ovipositor, whence the common name of "saw-flies." There are two broods each year. This is a common pest on the cherry, pear, plum, quince and crabs. See Fig. 9.

Remedies.—White hellebore (7) 1 ounce to 3 gallons of water, arsenate of lead (4), Black Leaf 40, 1 part to 800 or 1,000 parts of water; freshly slaked lime (27), or wood ashes (26) dusted upon the slimy larvae will kill many. A strong stream of water will wash them from the leaves.

Fruit-Tree Leaf Roller.—This insect attacks the plum, prune and cherry quite severely, and the peach to some extent. (See under Apple).

Brown Mite and Red Spider.—These are often quite bad on peaches and plums. For description and treatment, see under Apple and Pear.

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Fig. 18.—Small apricot limb with bark removed to show the galleries made by the larvae and adults, and holes made by the adults of the shot-hole borer or fruit-tree bark-beetle. Enlarged twice. After O. E. Essig, "Injurious and Beneficial Insects of California." Calif. State Com. of Hort.

BARK AND WOOD

Shot-Hole Borer.—Quite often cherry, plum, prune, peach and sometimes pear and apple trees are found that have numerous small holes in the bark. These will be about the size of a hole made by a small shot or the size of a pin head. These holes are made by the shot-hole borer as the adult beetles leave the trees. If the bark is cut away, numerous channels running between the bark and sap wood will is found. These are made by the grubs of the small brown beetles. See Figs. 18 and 19.

Fig. 19.—Adult of the Shot-hole Borer or Fruit-tree Bark-beetle. Enlarged five times. After O. E. Essig, "Injurious and Beneficial Insects of Calif." Calif. State Com. of Hort.

This borer very seldom attacks healthy, vigorous trees. It seeks those that have been weakened by disease or injury.

Remedies.—Keep trees in a healthy, vigorous condition. Destroy all infested trees by burning. Whitewash (15) will help to prevent sunscald and will, to some extent, keep beetles from laying eggs on the trees.

Scale Insects.—See under Apple and Pear.

Peach-tree Borer.—A yellowish-white borer about one to one and one-quarter inches in length when full grown. It bores beneath the

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bark of the lower trunk, crown and larger roots, often killing small trees by girdling them and damaging larger trees so much they are of very little value. The adult is one of the clear winged moths, and may be mistaken for a wasp. Besides the peach, this borer infests plum, prune, cherry and apricot. See Fig. 20.

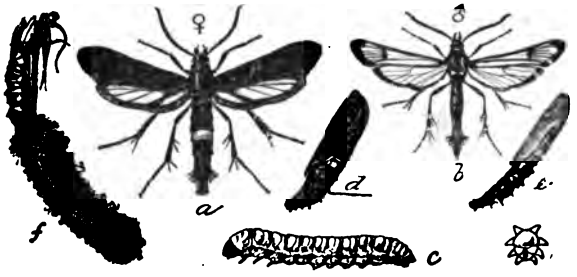

Fig. 20.—Peach-tree Borer: a, adult female; b, adult male; c, full-grown larva; d, female pupa; e, male pupa; f, pupa skin and cocoon. All about natural size. (Marlatt, Circular 17, Second Series, U. S. Dept. of Agriculture, Division of Entomology.)

Remedies.—Carefully inspect the trees every fall and spring and remove all borers with a knife. It may be necessary to remove some soil from about the crown to find all borers. Their presence is usually indicated by a gummy exudation upon the bark. A shield of paper about the trunk from June 1 to August 1, the egg-laying period, will aid in keeping the adults from laying eggs upon the bark. Asphaltum painted upon the trunks has been used for this purpose, in California with some success. See Fig. 21.

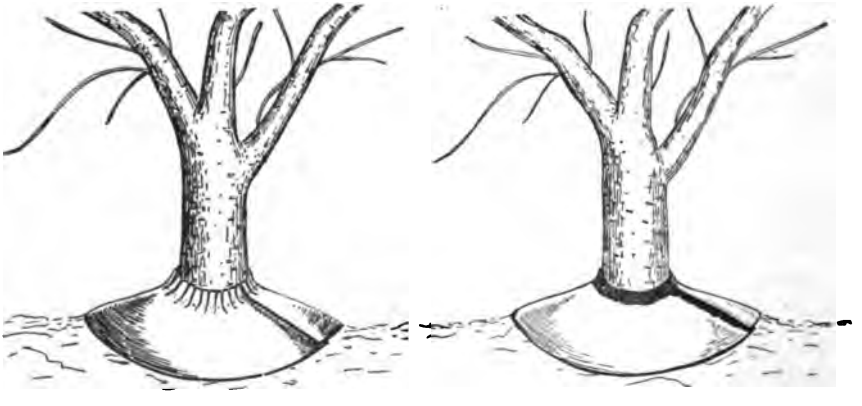

Fig. 21.—Showing a type of tree protector that gives results in controling the peach-tree borer. No. 1 shows the protector in place but not sealed to the tree. The adult lays her eggs on the trunk of the tree, the small newly hatched borers are unable to penetrate the dry tough bark of the tree trunk, so endeavor to crawl to the soil where the bark is moist and tender. The cone-shaped protector prevents them from reaching the base of the tree, and they soon perish. The protector must be closely sealed to the tree and all seams closed. (Loaned by the Scott Tree Protector Co., Baltimore, Md.)

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CURRANT AND GOOSEBERRY

FRUIT

Fruit Worm.—This is a flesh-colored worm about two-thirds of an inch in length when fully grown. It attacks both the gooseberry and currant in some parts of Colorado, and may destroy a considerable portion of the crop by eating large holes into the berries. It may enter a berry and eat out the interior and go on to another. Clusters of fruit and leaves are often loosely webbed together. The adult insect is a gray moth with rather long, narrow wings. See Fig. 22.

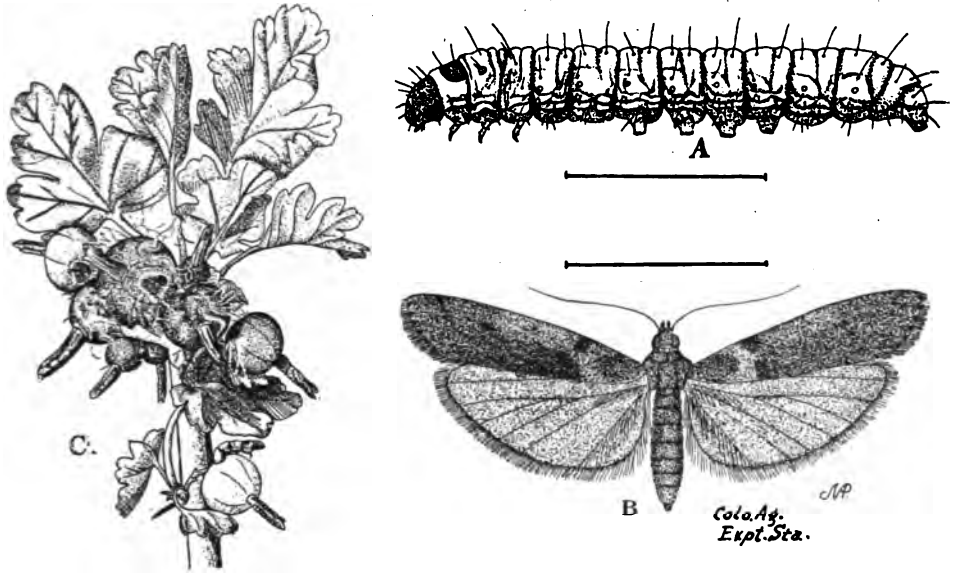

Fig. 22.—Currant and Gooseberry Fruit-worm; A, worm; B, moth; C, gooseberries webbed together. Original in Bull. 114, Colo. Agr. Col.

Remedies.—Hand picking is probably the best remedy. Destroy all web clusters. This is practical only on a small scale. Poison sprays would kill many, but would make fruit unsafe for food. Thorough cultivation will destroy many of the over-wintering chrysalids.

Fruit Maggot.—This is one of the most serious pests of the gooseberry and currant in Colorado. It is a small, white maggot which feeds within the fruit, causing it to turn red and drop. The adult is a two-winged fly about the size of an ordinary house fly, but yellowish-brown in color, with dusky bands across the wings. It comes out in the spring when the berries are about half grown and stings the fruit with its sharp ovipositor and deposits its eggs beneath the skin. In about three weeks the full grown maggot leaves the fruit and enters

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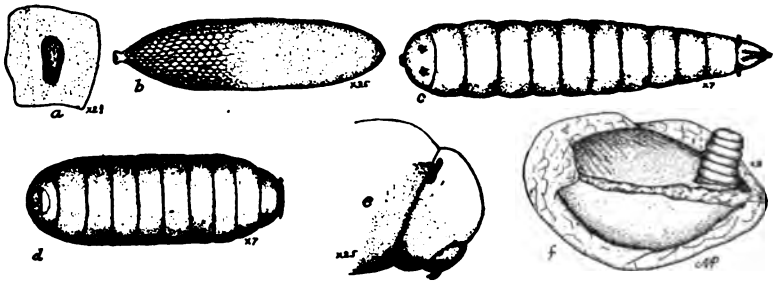

Fig. 23.—Currant and Gooseberry Fruit Maggot; a, egg puncture made in the berries by the adult flies; b, egg; c, larvae; d, pupa; e, head end of larva showing sharp jaws beneath; f, larva entering a seed; a, enlarged 2½ times; b, 35 times; c, d, 7 times; e, 25 times; f, 8 times. Original, Miriam A. Palmer, Delineator.

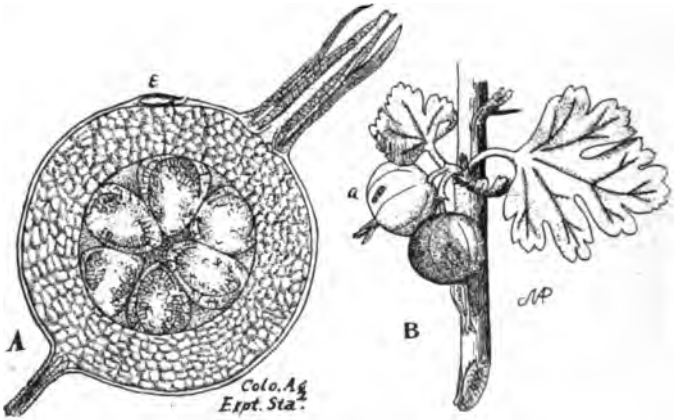

Fig 24.—Currant and Gooseberry Fruit-maggot: A, section through a gooseberry showing egg and puncture at e; B, two gooseberries on a stem showing egg puncture, or sting, at a. Original in Bull. 114, Colo. Exp. Sta.

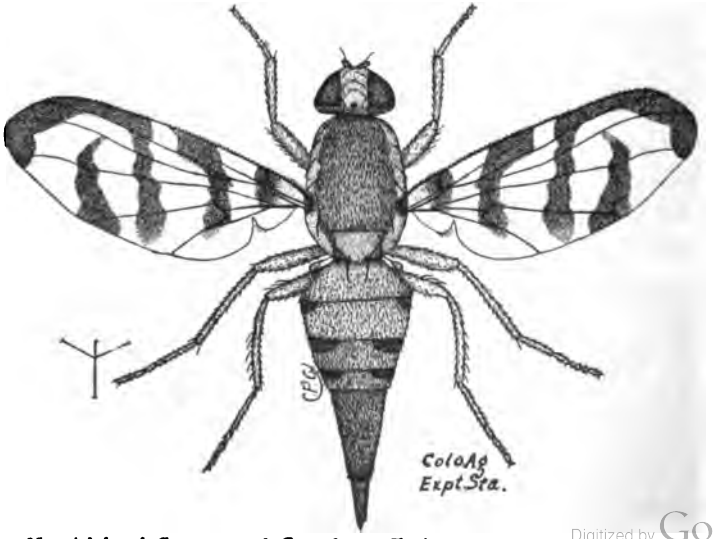

Fig. 25.—Adult of Curraan and Gooseberry Fruit-maggot.

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the ground where it hibernates. There is only one generation a year. See Figs. 23, 24 and 25.

Remedies.—No practical method of control has been found. Collecting and destroying the infested berries will help, but is impractical, except on a small scale. Thorough cultivation to destroy the hibernating form will help. Chickens running among the bushes will destroy many.

FOLIAGE

Native Saw Fly.—A light green worm with a blackish head that feeds upon the leaves of currant and gooseberry bushes. The first brood appears in June and the second in August. The adult insect is a black four-winged fly about the size of the house fly that appears in the spring while the leaves are small ,and inserts the whitish eggs in the edge of the leaf between the two outer layers. The eggs form a blister-like elevation on the leaf.

Remedies.—Four pounds arsenate of lead (4) or 1 pound Paris green (2) in 100 gallons of water will be found effective. These should not be used before the fruit is picked. The following may be safely used on the fruit, and are quite effective: White hellebore. 1 ounce to 3 gallons of water, or in the evening, thoroughly dust the leaves with the hellebore, or with pyrethrum.

Imported or European Saw Fly.—This pest has only recently been reported in Colorado. It is very similar to the preceding species, but is much more destructive. The larva can be distinguished from the native species by its dark head and numerous black specks on the body. The adult is somewhat larger than our native species. The small white eggs are placed in rows along the veins on the under side of the leaves.

Remedies.—Same as for the preceding species.

Currant Plant Louse.—The eggs are small shining black objects, and rather long in shape. They hatch, about as the buds begin to open, into a yellowish-green louse that feeds upon the opening buds and later upon the under side of the leaves. The numerous food punctures cause the leaves to curl and turn red and yellow in color. The lice remain on the currants all the season. Their favorite plant is the red currant, but they also attack the black currant and gooseberry.

Remedies.—Same as recommended for green apple aphis. The leaves curl so tightly, spraying must be done before they begin to curl, for best results.

Brown Mite and Red Spider.—These mites are often very abundant on currant and gooseberry. It is not uncommon to see bushes largely defoliated by them as early as July. See under Peach Foliage.

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BARK AND WOOD

Currant Borer.—A yellowish white larva, about one-half inch in length when mature, that tunnels into the canes, often killing them. It hiberates within the canes and comes out as a wasp-like moth in June. The moth very much resembles that of the peach borer, but is smaller. Infested canes can often be detected by the withered yellowish appearance of the foliage or the small burrow made to the surface.

Remedies.—Cut out and burn all infested canes as soon as detected. Keep the old wood well trimmed out.

Scale Insects.—The San Jose. Putnam, Oyster-shell, and several other species of scale insects may attack the currant and gooseberry.

STRAWBERRIES

Leaf Roller.—Small greenish-brown caterpillar that webs the two halves of the leaves together and feeds within the roll causing the leaves to wither and die. So much of the foliage may be destroyed that the fruit will not mature properly. See Figs. 26 and 27.

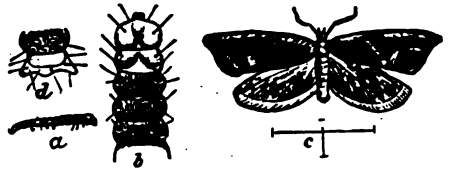

Fig. 26.—Strawberry Leaf-roller; a, larva, natural size; b, head end of larva enlarged; c, moth about twice natural size; d, tail end of larva enlarged. (After Saunders.)

The adult insect is a small dark brown or rust-colored moth with white markings on the wings; about one-half inch across expanded wings It also attacks the raspberry and blackberry.

Fig. 27.—Strawberry leaves showing their appearance after being folded. (After Weed.)

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Remedies.—New Jersey Experiment Station, Bulletin 225, reports success with arsenate of lead (4), 5 pounds to 100 gallons of water, applied before the leaves are rolled, or about one week after the moths appear in the spring. After the fruit is gathered, scatter straw over the plants and burn.

Strawberry Crown Borer.—This is a yellowish-white grub that eats into the crowns of the plants. It is the larva of one of the snout beetles.

Remedies.—Do not allow beds to get too old. If badly infested, gather only one crop before renewing. Place the new beds some distance from old ones. Burning over as recommended for preceding species is of some value.

Red Spider.—Often attacks strawberries. For remedies see under Apple, Peach and Pear.

RASPBERRY AND DEWBERRY

Raspberry Saw Fly.—A light green larva about three-fourths of an inch long when fully developed, that eats irregular holes in the leaves. The small white eggs are deposited within the tissue of the leaves by a fly resembling the cherry saw fly.

Remedies.—Same as for Saw Flies on currants and gooseberries.

Cane Borer.—Small cylindrical borer that eats into the new shoots during early summer, causing them to wither. It remains in the canes during second season eating downward through the pith, often killing the cane before the fruit matures.

Remedies.—Cut off all affected canes and burn while the borers are still in them.

Red Spider and Brown Mite.—Often attack the raspberries and dewberries. For remedies see under Apple Pear and Peach.

GRAPE

Leaf-Hopper.—Closely related and very similar to the leaf-hopper of the apple and pear. For description and remedies see under Apple and Pear Foliage. See Fig. 28.

Eight-Spotted Forester.—A caterpillar about one and one-half inches long when mature, dark colored with numerous small black and white cross lines on each body segment. The adult is a dark colored moth with eight light spots on the wings. See Fig. 29.

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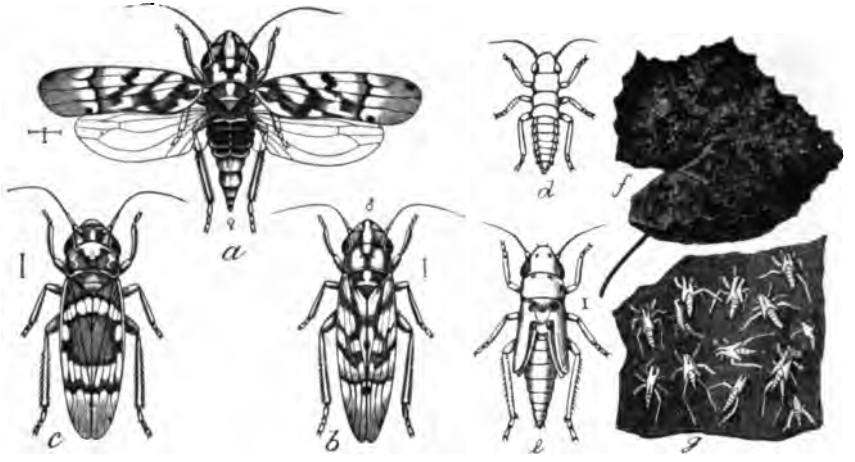

Fig. 28.—Grape Leaf-hopper; a, adult female; b, adult male; c, another form of the species, showing variation in markings; d, newly-hatched nymph; e, last stage nymph; f, appearance of injured leaf; g, cast pupa skins. a-e, much enlarged; g, less enlarged; f, reduced. (After Marlatt, U. S. Dep't. of Agr. Div. of Entomology.)

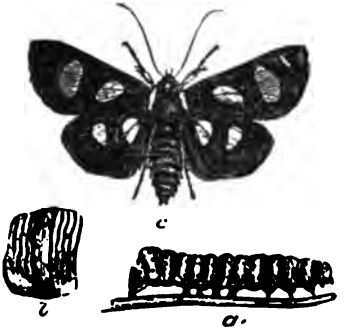

Fig. 29.—Eight-spotted Forester; a, larvae; b, one segment of body of larva enlarged; c, moth. Natural size, except b.

Remedies.—The arsenicals (2-4-5) will be found effective. In small vineyards hand picking might be found practical.

This insect also attacks the Virginia Creeper.

Cottony Scale.—See under Maple.

SHADE TREE PESTS

Cottony Maple Scale.—This insect winters over as partly grown brown scales on the smaller limbs and twigs. With the coming of spring the insect grows and throws out a white cottony secretion from the posterior end of the scale. During June, a mass of small creamy-white eggs are deposited in the cotton under the old scale. At this time the scales are very conspicuous. The eggs hatch during the last of June and early July and the young lice locate on the under side of the leaves. This is a common pest of the maple, and also infests black locust, elm, and many other trees and shrubs. See Fig. 30.

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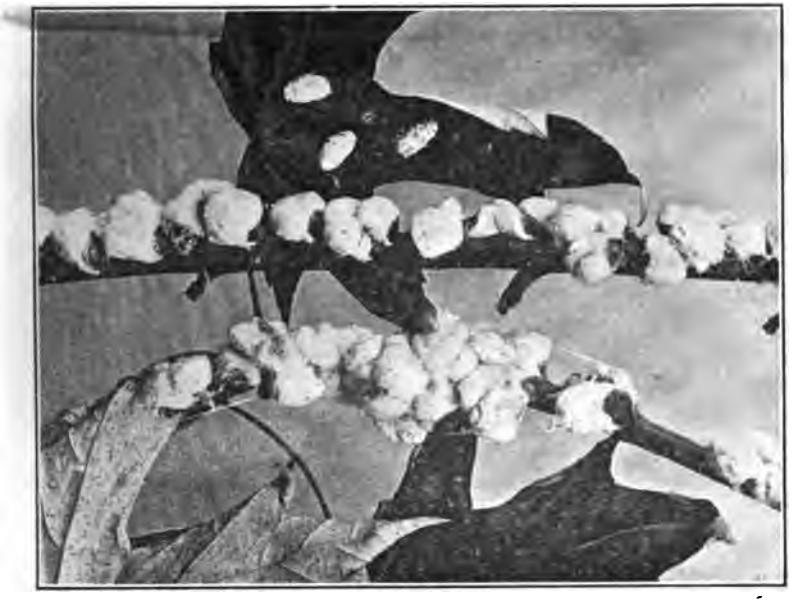

Fig. 30.—The Cottony Maple Scale. Mature females on maple twigs. Larvae of one of the lady-bird beetles, **Hyperaspis signata** Oliv. on leaf at the left. These lady-bird beetles feed on scale insects. Natural size. (After O. E. Essig, "Injurious and Beneficial Insects of Calif." Calif. State Com. of Hort.)

Remedies.—Kerosene emulsion (10), 15% kerosene, used during the dormant season, will be found fairly effective.

Tobacco extract (19) or kerosene emulsion (10), that is 7% kerosene, will destroy the young insects, but it is difficult to strike all of them on the under side of the leaves. If a strong current of water can be used, many of the young insects can be washed to the ground where they will perish.

Elm Scale.—The young lice hatch in June or early July and feed upon the leaves until fall, when they return to the bark, insert their beaks and hibernate during winter. In the spring the eggs are deposited under the body and a partial scale formed over the females. The presence of the insects is best indicated by the partial scale which consists of a white, waxy ring secreted about the insect. Infests elms only. See Fig. 31.

Remedies.—In Nevada where this has been quite a serious pest, best results have been obtained by using soluble oils (12), 1 part to 15 parts water, during the dormant season. For summer treatment use kerosene emulsion (10) or tobacco (19), as recommended for the maple scale.

Oyster-Shell Scale.—In some sections of the State this scale is quite bad on the ash and lilac. For description and remedies, see under Apple and Pear, Bark and Wood.

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Fig. 31.—The European elm scale on the American elm. Adult females as they appear in June. Natural size. (After O. E. Essig, "Injurious and Beneficial Insects of Calif." Calif. State Com. of Hort.)

Locust Borer.—A white grub about three-fourths of an inch in length when fully grown, that feeds within the trunk and limbs of the black locust, destroying many trees. Small white eggs are deposited in crevices of the bark during the early fall by the adult insect which is a wasp-like beetle about three-fourths of an inch in length. These hatch the same fall and the little borers eat into the bark where they live over winter. They mature the following July and the beetles come out during late summer and early fall. The presence of the borers can be detected by the borings that are forced out of the burrows.

Fig. 32.—Larva of Cottonwood Borer.

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Remedies.—Spraying is ineffective. Destroy all badly infested trees by burning. Many of the grubs can be killed and the life of valuable shade trees prolonged by squirting a small amount of carbon bisulphide into the burrows and plugging them with mud. This will necessitate going over the trees several times during early summer.

Fig. 33.—Cottonwood Borer, showing male and female moths. The female is larger.

Cottonwood Borer.—A large reddish caterpillar, head shining black, body somewhat flattened, and when mature about three inches long, bores large holes or galleries in the trunks of the cottonwoods and poplars. It transforms to a large thick-bodied moth in June and July. See Figs. 32 and 33.

Remedies.—This borer does not bring its borings out to the surface, so it can be detected only by the discoloration of the bark, due to sap leakage. The borers sometimes can be dug out with a stiff wire, or the channels opened and carbon bisulphide injected. (See under Locust Borer.)

Boxelder Leaf-Roller.—This is very similar in appearance and habits to the Fruit Tree Leaf-Roller. It seems to attack boxelder exclusively in Colorado.

Remedies.—See under Fruit Tree Leaf-Roller.

Plant Lice on Ash, Elm, Willow, Boxelder, Locust, etc.—Most all of our shade trees and shrubs are subject to the attacks of one or more

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species of plant lice. These vary somewhat in appearance and habits, but are all subject to the same treatment. Use contact sprays, as kerosene emulsion (10), tobacco (19), or soap (8).

ORNAMENTAL PLANTS

Rose

Plant Lice.—The rose is subject to the attacks of several species of plant lice.

Remedies.—Use contact sprays (10), (19), (8), being careful to spray the under side of the leaves where most of the lice will be found.

Saw Fly.—This is a greenish-yellow larva about one-half inch in length when fully grown, that eats the upper surface of the leaves leaving only the veins and lower epidermis. The adult is one of the saw flies very similar to the adult of the pear and cherry slug.

Remedies.—See under Pear and Cherry Slug. A strong stream if water will wash many of the larvæ from the leaves.

Leaf-Hopper.—The rose is quite commonly attacked by leaf-hoppers, closely related and very similar to the species attacking the apple and pear. For description and remedies, see under Apple and Pear Foliage.

The young wingless hoppers can be washed off the foliage with a strong stream of water and many of them killed.

Rose Scale.—This is a snow-white, nearly circular scale about one-tenth of an inch in diameter. It often infests blackberries, raspberries, and dewberries, as well as roses. See Fig. 34.

Fig 34.—The Rose Scale on wild blackberry. Only slightly enlarged. After O. E. Essig. "Injurious and Beneficial Insects of California." Calif. State Com. of Hort.

Remedies.—Spray during dormant season with No. 8, 16 or 17. The soap should be used one pound to one gallon of water.

Virginia Creeper

Eight-Spotted Forester.—See under Grape.

The Achemon Sphinx.—A hairless caterpillar that feeds upon the foliage. It resembles the large tomato "worm." When small it has a long spine on the last body segment. When nearly full grown the

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spine is represented by a shining black spot.

Remedies.—Hand picking will usually keep the insect in control. The arsenicals, 2, 4 and 5, are quite effective.

SWEET PEAS

Red Spider.—Many growers of this common flower find the lower leaves turning yellow and falling, and the vines stopping growth. This is usually due to the work of the Red Spider.

For description and remedies, see under Peach Foliage. Frequent drenching with the garden hose will do much to keep the spider in check and prevent its injuries.

Spraying from a home-made tower.

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PART II.

INSECTICIDES

THEIR PREPARATION AND USE

There are two general classes of insecticides, those used against insects which have jaws and bite off and eat parts of the leaves, fruit or whatever they feed upon, and those used against sucking insects that have mouth parts in the form of a beak or slender tube through which they draw the juices of plants or the blood of animals.

For biting insects, some form of an arsenical compound, such as Paris green or arsenate of lead is commonly used and the insects are killed by eating the poison. For the sucking insects, which take their food from inside the plants, some of the contact insecticides such as kerosene emulsion, lime and sulphur or tobacco, must be used.

Contact sprays are often very effective in destroying the eggs of insects, especially those that winter over in the egg stage, as this will permit of spraying during the dormant season when a stronger solution can be used without injury to the plants.

Insecticides are generally used in one of three forms—liquid spray, powder, and fumes or vapor.

SUBSTANCES THAT KILL BY BEING EATEN

Arsenic in some of its compounds is the cheapest and most efficient poison used. As a very small amount of soluble arsenic is injurious to vegetation, only the insoluble compounds can be used.

1. WHITE ARSENIC

Pure white arsenic, arsenic trioxid (AS_2O_3), which comes in the form of a white powder, is the cheapest form in which arsenic can be obtained, but since in this form it is soluble in water, it cannot be used as an insecticide where it is applied directly to vegetation.

2. PARIS GREEN

This is an arsenite of copper. It contains about 58% of arsenic (AS_2O_3). The National Insecticide Law requires that it contain a least 50% of arsenic trioxid.

For many years this was a standard arsenical insecticide for orchard use, but owing to the danger of injury to foliage, from some soluble arsenic present, it has been largely replaced by less soluble arsenical compounds.

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Paris green is often used in the dry form for dusting on plants. In this case it is better to dilute with some other material, such as flour, slaked lime, or plaster.

A good proportion is:

Paris green	1 pound
Common flour, lime or plaster	25 pounds

The flour will prove better than the other materials, as it will not be distasteful to insects and will adhere better to foliage.

When the Paris green is applied in a watery spray, the most common strength is:

Paris Green	1 pound
Water	160 gallons
Lump lime	2 pounds

For stone fruits it is safer to use 200 gallons of water. Make the Paris green into a paste, then slake the lime in a small amount of water and add to the Paris green. Dilute until it can be strained into spray tank. Keep the liquid thoroughly stirred during application, as the Paris green settles out very quickly.

3. Poison Bran Mash

The following poison bran mashes have been found quite effective in destroying grasshoppers in orchards and vineyards, and army worms and cutworms when abundant:

White arsenic or Paris green	1 pound
Bran	20 pounds
Syrup	2 quarts

This formula has been used for a number of years, but Professor George A. Dean of Kansas has developed the following formula that is highly recommended:

Paris green	3 pounds
Bran	50 pounds
Syrup (cheap)	4 quarts
Water	5 gallons
Lemons	40

Mix the Paris green and bran together while dry; dissolve the syrup in the water; squeeze the lemons into this and finely chop the peel and pulp and add them also; pour this mixture into the bran and Paris green, and stir so as to dampen the mash thoroughly. The lemons may be prepared by putting them through a meat grinder. Distribute the mixture broadcast in as fine particles as possible where the grasshoppers are most abundant. The application should be made towards evening or early (between 4 and 7 o'clock) in the morning. From 3 to 5 pounds of dry bran is usually sufficient for an acre of land. Never distribute in little piles. For army worms, distribute more freely just ahead of the line of march.

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4. ARSENATE OF LEAD

Arsenate of lead (paste) .....3 to 6 pounds
Water .....100 gallons

It is better to purchase arsenate of lead than to attempt to make it. This is the standard spray for codling moth and other biting insects. It has replaced the other arsenicals in practically all cases.

This poison is so completely insoluble in water that it can be used in most any strength without injury to foliage or fruit. The fineness of the particles causes it to settle very slowly, and consequently it can be more evenly distributed than most arsenical compounds. In adhesiveness it is superior to other arsenicals, but has the fault of not killing as quickly as Paris green.

Arsenate of lead is sold in both the form of a paste and as a powder. Under the National Insecticide Law, the paste must not contain more than 50% water and must contain arsenic equivalent to 12½% arsenic trioxid (AS_2O_3). The water soluble arsenic must not exceed the equivalent of three-fourths of one percent of arsenic.

The paste has been more generally used than the powder, but if the powder is fine enough to remain in suspension when mixed with water, the results will be as good. One pound of powdered arsenate of lead is equivalent to two pounds of the paste form.

In preparing both the paste and powder forms for the spray tank, mix them first into a very thin paste. Never throw them as a mass into the spray tank.

5. ZINC ARSENIC

This is an arsenical compound that is comparatively new as an insecticide. It is being quite extensively used on the Pacific coast as a substitute for arsenate of lead. This is a light fluffy powder containing arsenic equivalent to 40 percent arsenic trioxid. It goes into suspension in water very readily and remains in supension better than arsenate of lead or Paris green. In 1912, severe burning resulted in many apple orchards on the Western Slope where it was being tried out by the growers. One pound is equivalent to three pounds of arsenate of lead.

6. BORDEAUX MIXTURE AND THE ARSENITES

Bordeaux mixture has been a standard fungicide for many years, and besides the fungicidal properties, it acts as a repellant to certain insects, especially the flea-beetles. It has also been demonstrated that it has the effect of lessening the burning effect of Paris green, arsenite of zinc and other arsenicals, without injuring their poisoning qualities. Such a mixture will destroy both insects and fungi at one application.

A standard formula for Bordeaux mixture is:

Bluestone (copper sulphate)..... 4 pounds
Lime (unslacked) ..... 5 pounds
Water ..... 5 gallons

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Dissolve the blue stone by suspending it in a sack in water, then dilute to 25 gallons. Slack the lime into an even creamy paste and then pour it into the bluestone solution slowly and dilute to 50 gallons. Never add the concentrated lime solution to the bluestone solution until the latter has been diluted.

If poisons are to be used with the Bordeaux, use them according to the proportion given for the different poisons, considering the Bordeaux as water.

7. WHITE HELLEBORE

Hellebore is a yellowish white powder made from the roots of a plant (*Veratrum album*) belonging to the lily family. It, being a vegetable poison, is not injurious to foliage. It is very effective against certain insects, especially the slugs which are the larvae of saw flies.

When exposed to the air, hellebore loses its strength, so a fresh article should always be demanded. Due to this fact, it is considered safe to use it on ripening fruit. It is often used on the cherry to control the cherry slug up to picking time. It is applied both dry and in water. When applied dry, it may be used without dilution.

When applied in water use:

White hellebore	1 ounce
Water	3 gallons

SUBSTANCES THAT KILL BY EXTERNAL CONTACT

Contact insecticides are especially effective against soft bodied insects.

Contact sprays have been developed, primarily, to use against sucking insects, but many of the chewing insects may be destroyed by them. To get results, thoro spraying must be done, as only those insects that have the material thrown directly upon them will be killed.

8. SOAP

Soap solutions are often used as contact insecticides against plant lice Quite often, if one has only a few small trees or bushes in the garden, they may be treated with a solution of ordinary laundry soap, one pound to six gallons of water.

The whale oil or fish oil soaps are more effective. Use one pound to six to ten gallons of water.

9. FISH OIL SOAP (HOME MADE)

Slingerland and Crosby in their "Manual of Fruit Insects" give the following formula for the preparation of fish oil soap:

Caustic Soda	6 pounds
Water	½ gallon
Fish oil	22 pounds

"Completely dissolve the caustic soda in the water, and then add the fish-oil very gradually under constant and vigorous stirring. The combination occurs readily at ordinary summer temperatures and boil-

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ing is not necessary. Stir briskly for about twenty minutes after the last of the oil has been added."

Use:

Soap	1 pound
Water	6 to 10 gallons

10. KEROSENE EMULSION

Soap (whale-oil or common soap)	½ pound
Water	1 gallon
Kerosene	2 gallons

Dissolve the soap in the water by boiling. Remove from the fire, and while still hot mix with the kerosene. Agitate vigorously by driving it through a spray pump until the oil is well emulsified and a uniform cream-colored mixture is produced. Small amounts may be emulsified by stirring vigorously, or by using a rotary egg-beater.

Dilute this stock solution by using one part to 10 or 12 parts water for a summer spray. For use on dormant trees, use one gallon of the stock solution to 5 to 7 gallons of water.

The strength of an oil emulsion depends upon the percent of oil it carries. The strength of the emulsion to use is often indicated by this percentage.

To obtain the amount of dilution to secure a certain percent. divide the percent of kerosene in the stock solution by the percent desired in the diluted emulsion and the result will be the amount to which one gallon should be diluted. As one gallon of the stock solution made according to the above formula will carry sixty-six and two-thirds percent of kerosene, to obtain the amount to which it should be diluted to get a 12½ percent emulsion, divide 66 2-3 by 12½, which gives 5 1-3. One gallon diluted to make 5 1-3 gallons will give a 12½ percent emulsion.

Summer sprays should carry from 5 to 7 percent kerosene, and sprays for dormant trees from 10 to 15 percent.

11. KEROSENE AND CRUDE PETROLEUM

These oils are sometimes used pure as insecticides. Some years ago they were used quite extensively in parts of the East in specie spraying machinery that diluted them with water as they were being applied to the trees. Other sprays equally effective and much safer to use on trees have taken their places. Many growers use them in painting or swabing the clusters of woolly aphis that gather about wounds on apple trees.

12. SOLUBLE OR MISCIBLE OILS

There are several concentrated oil emulsions on the market known as soluble or miscible oils. These are used almost entirely as dormant

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sprays against the scale insects and certain other insects that winter over in the egg stage on the trees. They are subject to the same criticism as all other oil sprays, that of being more or less injurious to trees under certain conditions. To lessen the danger of injury they should be applied only while the trees are dry and the temperature fairly high, at least several degrees above freezing. In their work in the Eastern states, they have found the danger of injury less if applied after the sap begins to flow, and just before the buds open.

Only "soft" water should be used in any of the oil sprays, as a very small amount of alkali will tend to break down the emulsion and give free oil.

13. GASOLINE

Gasoline is sometimes used as an insecticide. Its chief use is against bed-bugs. It is destructive to both the adults and eggs. It is applied pure by means of an oil can or hand atomizer. Keep all fire away until the building has been well aired.

14. TURPENTINE

Turpentine is used the same as gasoline, and the same precautions apply. It is more deadly to bed-bugs.

15. LIME

Lime, either wet or dry, is of very little value as an insecticide. It is sometimes used to dust trees that are infested with the cherry and pear slug, it causes the slugs to drop off and most of them perish. Any other fine dust will have the same effect.

Whitewash on trees destroys very few insects but often prevents sun scalding. A good wash for this purpose is made in the following proportions:

Lime (lump)	30 pounds
Tallow	4 pounds
Salt	5 pounds
Water to make it flow well.	

The Government recommends the following formula:

Lime (unslacked)	40 pounds
Salt	15 pounds
Rice flour	3 pounds
Spanish whiting	½ pound
Glue	1 pound
Water	5 gallons

Slack the lime and strain. Boil the rice and dissolve the salt and glue in warm water. Add the materials to the slaked lime in the following order stirring well all the time: salt, boiled rice, Spanish whiting, glue, and water. Let stand for a few days before using, then apply hot.

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16. LIME-SULPHUR WASH

This is the safest and most effective spray that can be used against the San Jose and other kindred scale insects.

The old formula that is still quite generally used is:

Lump Lime	20 pounds
Sulphur	15 pounds
Water	50 gallons

The lime is slaked with hot water in the kettle or cooking vessel, the sulphur is then stirred in and about one-half of the water added, then cooked from 50 to 60 minutes, or until the liquid becomes of a dark red color. when it is ready to dilute to 50 gallons, and use. Best results are obtained when it is applied while hot.

17. HOME-MADE CONCENTRATED SULPHUR

Fruit growers who have considerable lime sulphur spraying to do can make their own concentrated solution. This can be made and stored in tight barrels for future use, and if properly made and diluted according to the amount of sulphur it carries, it is just as effective as the commercial preparations.

With the present prices of the commercial products the grower will find the home-made solution much cheaper, except for the original outlay for a cooking plant and storage barrels.

In making this mixture the same methods are used as given above for making the dilute solution, but the following formula is used:—

Lump lime (pure)	40 pounds
Sulphur	80 pounds
Water	50 gallons

Use only the best grade of pure lump lime. In boiling, never allow the water to get below 50 gallons, as this amount is required to carry the sulphur in solution. A mark showing the 50 gallon line should be made on the kettle or on the stirring paddle. If the mixture is to be stored for future use, strain into an air tight container and keep where it will be above the freezing point.

Home-made concentrates are apt to vary more in strength or density than the commercial brands. For this reason, each cooking should be tested and diluted according to the amount of sulphur in solution. This test is made by the Baume hydrometer, an instrument made for testing the density of liquids.

The hydrometers are manufactured by the Bausch & Lomb Optical Company, Rochester, N. Y.

The following table taken from Bulletin 330, New York Agricultural Experiment Station will be found useful in making dilutions from the hydrometer readings.

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Reading on Hydrometer, Degree Baume.	Specific gravity.	With each gallon of concentrate use for San Jose Scale:
35	1.3181	9 gallons water
34	1.3063	8½ gallons water
33	1.2946	8 gallons water
32	1.2831	7¾ gallons water
31	1.2719	7½ gallons water
30	1.2608	7 gallons water
29	1.2500	6¾ gallons water
28	1.2393	6½ gallons water
27	1.2288	6 gallons water
26	1.2184	5¾ gallons water
25	1.2083	5½ gallons water
24	1.1983	5¼ gallons water
23	1.1885	4¾ gallons water
22	1.1788	4½ gallons water
21	1.1693	4¼ gallons water
20	1.1600	4 gallons water
19	1.1507	3 2/3 gallons water
18	1.1417	3 1/3 gallons water
17	1.1328	3 gallons water
16	1.1240	2 4/5 gallons water
15	1.1153	2½ gallons water

18. Tobacco

Tobacco in one form or another has come to be one of the most generally used and the most effective insecticides. In the shape of a fine powder it is sometimes used against flea-beetles; the dust made from the stems is one of the best remedies we have for woolly aphis on the roots of the apple trees.

19. Tobacco Extracts

There are several commercial tobacco preparations on the market. Those most generally used are "Black Leaf 40" and "Nicofume." These both contain about 40 percent nicotine which is the poisonous principle in tobacco. This is one of the most deadly poisons known. It is soluble in water and entirely volatile when pure. In Black Leaf 40, the nicotine has been treated to form a sulphate which is non-volatile. Black Leaf 40 is used in strengths varying from 1 part to 800 parts of water to 1 part to 1200 parts. Three pounds of soap added to each 100 gallons will make it spread and stick better. When used against the woolly aphis, the soap will aid the mixture to penetrate the woolly covering of the lice.

Black Leaf 40 can be combined with arsenate of lead and lime-sulphur sprays, but should not be used with arsenite of zinc.

Nicofume is used almost entirely for green-house insects. The nicotine being volatile, it will not stay on the plants long.

Its principal use is to soak material from which a smudge is made. The nicotine is driven off and destroys the insects.

Tobacco decoction is sometimes made by steeping one pound of tobacco in 4 or 5 gallons of water. Do not boil, as this will volatilize the nicotine.

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20. SULPHUR

Flowers of sulphur has been found to be very destructive to the mites and red spider. It can be dusted on the plants in the dry form or may be mixed with water, one pound to three gallons, and used as a spray. First stir the flowers of sulphur into a small quantity of soapy water and then dilute to the desired proportion.

The mixture must be stirred vigorously, as the sulphur settles very quickly.

21. HOT WATER

Hot water may be employed to kill insects and eggs upon dormant nursery stock. Temperatures from 135 to 145 degrees for 10 seconds are usually harmless to dormant plants, and will kill all aphis eggs.

In some tests made at the college, those trees submerged for 10 seconds in water of 145 degrees were slightly injured, but 5 seconds in this temperature killed plant lice eggs, and showed no injury to the stock. One hundred thirty degrees was not very effective on some eggs treated. Probably the safest and most effective temperature is 135 to 140 degrees, with 10 seconds submergence.

SUBSTANCES THAT KILL BY BEING INHALED

22. CARBON BISULPHIDE

This is a colorless liquid with a very disagreeable odor. It is very volatile and the fumes are poisonous to both plant and animal life. Its chief use as an insecticide is against household and granary pests, borers and under-ground insects. For household and granary pests, use one pint to each 1000 cubic feet of space or for each 100 bushels of grain. Place in shallow vessels so it will evaporate quickly. Keep building closed for 24 to 36 hours.

For borers, by means of an oil can, squirt a few drops of carbon bisulphide into openings made by the borer, then plug with mud. Ants can be destroyed by punching a hole or two in their nests and pouring in one or two ounces of the liquid, after which the hole should be closed, and a wet blanket thrown over the hill. It is sometimes used against the woolly aphis on apple roots by making several holes 6 to 12 inches deep and about a yard apart about the tree and pouring 1 or 2 ounces of the liquid into each hole. Close the holes immediately.

Caution: Keep all fire away while using this material, as the gas is very explosive when mixed with air.

23. HYDROCYANIC ACID GAS

This is the standard fumigant for most horticultural purposes, and is often used to destroy insects in dwellings and mills. Many states require all nursery stock sold within the state, to be fumigated with this gas.

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The following formula has been adopted in most states as the standard for fumigating nursery stock:

Potassium cyanide (of 98 percent purity)	1 ounce
Commercial Sulfuric acid	2 ounces
Water	4 ounces

The above quantities are sufficient for 100 cubic feet of space. Submit the nursery stock to the fumigation for from 40 to 60 minutes. For fumigating dwellings, mills, clothing, and the like, it may be used even stronger, and should run several hours.

This gas is sometimes used in fumigating green houses, but as there is great danger of it injuring the tender plants, it should be used only by those of experience. For this purpose, the quantities given in the above formula are used to each 1000 cubic feet of space. Fumigate only at night, and while plants are dry, as sunlight and moisture make the gas more injurious to vegetation. Leave the house closed for 5 or 6 hours before airing, and air well before entering.

In mixing the materials, use only an earthern or wooden vessel, and add the materials in the following order:

First, put in the water, then add the acid slowly. Put the required amount of cyanide in a thin paper bag, and when all is ready, drop it into the liquid and leave the room as quickly as possible. The gas is very poisonous and almost odorless. One breath of it when strong may mean death. Never enter the fumigation room until it has been aired 30 minutes.

All buildings should be made as tight as possible before fumigation starts. Nursery stock may be fumigated in a tight box or a house prepared especially for this work. Such a house should be built with two thicknesses of matched boards, with building paper between. Ventilators should be provided and doors made tight-fitting.

Handle the potassium cyanide with great care remembering it is a deadly poison.

REPELLANTS

24. NAPTHALENE FLAKES, GUM-CAMPHOR, AND MOTH BALLS

These are used as repellants against fleas, clothes moths, museum pests, chiggers, etc. Scatter the repellants about the infested materials. They are often used in insect boxes and packed in with furs, feathers, and woolen goods to keep out insects that feed upon these animal products. They are not used to kill insects.

25. COMMERCIAL REPELLANTS

There are several commercial repellants upon the market that are of some value in protecting stock from flies. These can be secured at most any drug store.

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26. ASHES

Wood ashes dusted upon plants while they are moist, has the tendency to keep certain insects away, especially flea-beetles and cucumber beetles. It does not kill the insects, but makes their food distasteful.

27. LIME, PLASTER AND ROAD DUST

These are used like ashes as repellants against flea-beetles and cucumber beetles, but are of little or no use in destroying insects, except, possibly, the pear and cherry slugs.

INSECT TRAPS

28. LIGHTS

Many night flying insects are attracted by lights. The lights are placed over a vessel containing water with kerosene over the surface. The insects fly against the lights and fall into the kerosene and water. Many beneficial insects are also destroyed in this way, so it is doubtful if it is very practical except in rare cases. Not all night flying insects are attracted by lights. Such an insect is the codling moth. Some of those that can be caught in this way are the adults of the army-worm, cut-worms, corn, or boll-worms, and the beet web-worm.

29. BANDAGES

Burlap or other heavy cloth bands placed about the trunks of apple trees are very useful in capturing the larvae of the codling moth, as they leave the fruit and search protected places to spin their cocoons. If the loose bark is scraped from the trees, 50 to 60 percent of the larvae leaving the fruit can be caught. This is a very important help in cleaning up a badly infested orchard.

The bands should be of three thicknesses of cloth. Wrap the band loosely about the trunk, lap the ends, and fasten with a tack. They should be placed on the trees by the 15th of June. Remove them every ten days until the 20th of August, and kill all larvae, then remove when convenient after picking time.

30. HOPPER-DOZERS OR HOPPER-PANS

The hopper-dozers are useful in catching the jumping insects, especially grasshoppers. They consist of a large pan carrying water with kerosene on it, so arranged that it can be drawn across the field by a horse. The back of the pan should be extended until it is four feet high. The insects jump against this and fall into the water and oil.

31. STICKY MATERIAL

Bandages of sticky material are often placed around the trunks of trees to keep insects from climbing to the branches. The most

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common of these is "Tree Tanglefoot." manufactured by O. & W. Thum Co., Grand Rapids, Michigan. Printers ink or any other sticky material may be used. Where any oily substance is used, it should be put on a heavy paper bandage so as not to come in contact with the bark of the trees.

THE APPLICATION OF INSECTICIDES

The Pumps

Much of ones success in controling any of the insects will depend upon the efficiency of his spraying machinery. The spraying must be thoroly done, and at the right time to bring results. All pumps and supplies should be on hand and in good condition before it is time to start the work. The insects will not wait upon the tardy fruit grower.

Do not make the mistake of getting too small a pump. Small hand pumps have their place in spraying shrubbery and garden vegetables, but should not be purchased for orchard work. The larger hand pumps fitted to a barrel will do fairly good work in an orchard of medium to small trees, but in a commercial orchard the labor of pumping is too great, and is almost sure to result in a poor job being done. In such orchards, gasoline power outfits are most useful. They will carry a higher, more uniform pressure and do the work more cheaply. It is a matter of economy to use tanks that will hold 200 or 250 gallons.

All pumps should be fitted with brass valves, as the materials used will corrode valves made of other metals and harden and decompose leather valves. It is important to have the barrel or tank fitted with an agitator that will keep the liquid well stirred so the materials in suspension will not settle. The hose to which the nozzles are attached should be light as possible, yet strong enough to stand the high pressure.

APPLICATION OF DRY INSECTICIDES

There are various dust sprayers, both large and small, upon the markets. They are planned to distribute the dry insecticides upon the plants. The worst objection to these, especially the smaller ones is that they do not feed regularly, hence do not give a uniform flow of powder.

Small trees and low plants can be treated by dusting the powder through a cheese cloth bag, but it will reach the upper surface of the leaves only. It is best to apply the dust early in the morning, or in the evening, when there is sufficient moisture to cause it to stick where it falls.

HOW TO SPRAY

Lack of thoroness in spraying causes more failures than any other one cause. If insects are to be killed by poisoning, it is important

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to cover all their food with the poison; if they are to be killed with a contact spray, it must hit the insect. The first requisite is a man to hold the nozzle who knows what thoro spraying is and is not afraid to do it. The second is a pump that will give plenty of pressure, and the third is a nozzle that will break the liquid into fine particles. The liquid should be strained into the barrel or tank, so there will be no solid particles large enough to clog the nozzle.

With the poison insecticides, the best results follow when the leaf is covered most completely and uniformly with the spray mixture. This is best done by making a spray fine enough so that it will fall on the leaf in mist-like particles and dry there. The aim should be to cover every leaf in this way. In order to do this, it will be necessary to spray the tree from all sides and angles. Do not make the mistake of having the spray so fine it will not carry into the tree enough to reach the inner limbs.

In applying the contact insecticides, the spray should be coarse enough to wet the insects when it strikes them and to penetrate the woolly covering that some insects have.

In applying the first spray for the codling moth, when the object is to fill the calyx cups of the little apples with the liquid, the best results are obtained with a medium coarse spray that will thoroly wet all parts of the blossom end of the fruit. By this is not meant a spray made up of coarse drops, but one that is broken into fine particles, but still with body enough to carry 8 or 10 feet from the nozzle without going into a mist or fog.

It is important to have the nozzle on an 8 foot rod, at least, and at an angle of about 30 degrees. This will permit one to reach the higher parts of a tree and spray them from different angles. When spraying large trees, the work is greatly facilitated by having a tower arranged on the machine so that one man can spray from an elevated position. This is especially important in putting on the first codling moth spray. At this time a large percent of the little apples are directed upward and the spray can be thrown directly into the calyx cups.

NOZZLES TO USE

There are two types of nozzles that are used extensively, the Bordeaux type that throws a flat spray, the fineness and volume of the spray being regulated by the size of the stream that is thrown against a flat face of the nozzle; and the Vermorel or whirl-pool type that throws a cone shaped spray which may be graded from coarse to fine, depending upon the pressure and the size or the aperture in the plate. The latter have been greatly improved by giving

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them a center drive that produces a solid cone of spray, instead of the hollow cone. With the solid cone there is less likelihood of missing parts of the plants, and the wind does not catch the spray as badly. Good work can be done with both types of nozzles.

STATION BULLETINS

All available bulletins will be sent free on request to residents of this State.

The following are bulletins that are available at the present time:

No. Title

135.—A Few Orchard Plant Lice.
150.—Measurement and Division of Water.
157.—Arsenical Poisoning of Fruit Trees.
168.—Deterioration of Manures Under Semi-Arid Conditions.
169.—Some Insect Mites Attacking the Peach in Colorado.
170.—Thinning the Winesap.
172.—Garden Notes.
173.—Notes on a Dry Land Orchard.
174.—Adobe as a Building Material for the Plains.
176.—Productiveness and Degeneracy of the Irish Potato.
177.—Hold-over Blight in Pears.
182.—Colorado Climatology.
183.—Deterioration in Quality of Sugar Beets.
186.—Fixation of Nitrogen in Colorado Soils.
187.—Feeding Experiment with Lambs.
188.—Ration Experiments with Swine.
189.—Cost of Beef Production on Enclosed Range.
190.—Variation Studies in Brome Grass.
192.—Home-made Cider Vinegar.
193.—Nitrifying Efficiency in Colorado Soils.
194.—Frictional Resistence in Artificial Waterways.
195.—Small Fruits for Colorado.
196.—Some Soil Changes Produced by Micro-organisms.
197.—Hog Cholera and Necrotic Stomatitis.
198.—Onion in Colorado.
199.—Vegetable Growing in Colorado. Common Insects of the Garden.
200.—Silos and Silage.
201.—Mushrooms.
203.—Farm Costs on the Colorado Agricultural College Farm.
204.—Brisket Disease. High Altitude Disease of Cattle.
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207.—Some Miners' Inch Measuring Devices.
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209.—Irrigated Agriculture in the San Luis Valley.
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211.—Colorado Plants Injurious to Livestock.
212.—Fungous Diseases of Colorado Crop Plants.
213.—Poultry Raising in Colorado.
214.—Forage Crops for Colorado Plains.

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The Agricultural Experiment Station
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COLORADO PLANTS INJURIOUS TO LIVESTOCK

BY
GEO. H. GLOVER and W. W. ROBBINS

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COLORADO PLANTS INJURIOUS TO LIVESTOCK

By Geo. H Glover and W. W. Robbins

INTRODUCTION

Since Colorado is a mountainous state, with a considerable area of the plains district "above water," it is reasonable to assume that grazing under open-range conditions will always be an important factor in the livestock industry of the State. Poisonous plants have a special economic significance in the breeding and handling of livestock under these conditions. It is impossible to estimate, with any considerable degree of accuracy, the aggregate loss to the livestock industry from poisonous plants, but roughly estimating the known losses in certain counties, we may safely assume that it amounts to several millions of dollars annually.

The Experiment Station receives many letters of inquiry relative to plants that are suspected of being detrimental to livestock and many specimens are sent for identification. This bulletin is calculated to assist stockmen and farmers in the identification of poisonous plants, to offer a few suggestions relative to preventive and remedial measures and to site special conditions under which certain plants are known to poison animals. The authors have attempted, by illustration and description, to correct some popular errors in the identification of certain plants that, in appearance, have a striking resemblance, such as the death camas and wild onion. Again, space is given to consideration of several plants, like algae and corn smut, which are incorrectly thought to be poisonous.

CONDITIONS OF POISONING

It is important to know the conditions under which poisoning is most liable to occur. There can be no doubt that animals, when left to themselves, will by instinct exercise considerable judgment in the selection of their food. Experience has shown that more animals are poisoned when being crowded by the herdsman, and, in case of cattle, when they are handled at the time of "round-up." When being driven, animals will grab at weeds that they would not otherwise touch.

When animals are very hungry they are not very particular in the selection of their food. Many disastrous cases of poisoning occur when cattle and sheep are taken directly from the yards to the ranges after a long shipment.

Larkspur, and probably some other plants, are known by experience to be far more poisonous when the foliage is wet from dew, rain or snow. When poisonous plants, like the death camas, start to grow in advance of the native grasses, they are eaten almost to

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the exclusion of everything else. An acrid, bitter or otherwise disagreeable taste does not always bar stock from eating the first green food that appears in the spring time. Again in the late summer the native grasses often cure early from drought and injurious plants like loco and lupine remain green. It is obviously true that stock will eat most poisonous plants that are green in preference to grass that has dried up and this no doubt accounts for the loco habit being acquired more often in the late summer and fall.

The stage of growth has much to do in determining whether or not certain plants will be eaten at any particular season of the year. The larger species of larkspur and the water hemlock become coarse and objectionable after flowering and are seldom eaten. On the other hand, some plants are relished throughout the period of their growth. The death camas is eaten with avidity just before the flowering stem is formed; equisetum is eaten more after being cured with the hay, and matured lupine with the seed pods appears to be relished by sheep. To analyze all of the conditions under which poisoning occurs seems to be a hopeless task. The subject is complex. In the realm of poisons we are still groping in the dark, and there are many mysterious cases of poisoning that are quite unaccountable.

The reputation of a plant as poisonous or non-poisonous may be affected by many circumstances. It is found to be true that certain parts of a plant may be poisonous while other parts are not, and that the quantity of poison in any particular part may vary widely under different soil and climatic conditions and at different periods of growth. It is necessary to know the entire history of a plant before declaring it poisonous or non-poisonous. For example, the poison in lupines is confined almost entirely to the seeds, and if cut before going to seed makes a fair quality of hay. In water hemlock the poison is found largely in the roots of the mature plant. In calabar bean the very poisonous alkaloid eserine is found in the cotyledons. In aconite seeds, the central part contains most of the aconite. Not only may the amount of poison in any particular part of a plant vary greatly at different stages of growth, but it has been shown by Dr. J. P. Lodsy, in Java, that in case of cinchona the amount of akaloid in the leaves varies greatly between night and day and that the alkaloid is formed in the leaves during the day and deposited in the branches or bark during the night. Because of the fact that the most active principle in most plants is not uniformly present in any particular part of the plant, there is, as might be expected, contradiction in rating plants as poisonous or non-poisonous. It is a matter of common observation that while a large number of animals in a herd may be poisoned, a few almost invariably escape, and all are seemingly under the same conditions. The num-

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ber poisoned and the degree of poisoning depend upon three factors: The quality of poison, the quantity of poison, the racial as well as individual susceptibility to the particular poison in question. There is the greatest diversity in animals as to susceptbility to poisons. In Prof. Rudolph Kebert's text on Practical Toxicology is found the following information bearing on this subject: "The smallest snail will withstand more strychnine than an adult man. Many of the strongest cardiac poisons have no action whatsoever upon insects. Great care is necessary in thus reasoning from even the effects noted in experiments with warm-blooded animals approaching nearer to man. The rabbit can take more morphine than can a man of fifty times the animal's weight. Doses of lead, nicotine cytisin, etc., sufficient to fatally poison do not injure the goat. Amygdalin does not affect dogs, but it kills rabbits. The hedge hog takes with apparent enjoyment, a dose of cantharides that would kill several persons under excruciating pain. The bite of the most venomous snake does not harm him; he can even accommodate no inconsiderable quantity of hydrocyanic acid. Whereas the frog is extraordinarily susceptible to the digitalis poisons, they have no effect upon the toad."

Another factor that complicates the grazing of animals, on a range where there are poisonous plants, is the uncertainty of their feeding habits; this is especially true of sheep. It is not an uncommon experience to see sheep eating greedily of plants that they have not been seen to eat before and will not eat the day or week following. This seemingly unaccountable appetite may be manifested in eating either poisonous or forage plants and may be true of the entire band or a few individuals. When a few individuals have been poisoned, it is safer to conclude that they alone have been eating certain poisonous plants than it is to assume that they were the only ones that were susceptible. In most cases it will be found that a majority of the band will be eating largely of certain plants, and where the small species of larkspur and death camas are both growing they will eat largely of one or the other throughout the season. All things considered it is impossible to predict with any degree of certainty whether or not animals will eat of a particular poisonous plant if allowed to graze unmolested.

PREVENTIVE MEASURES

Much more can be accomplished in prevention of poisoning than in treatment of animals after they have been poisoned. This principle is generally recognized to be true in its application to all diseases, and is especially true in this instance, for the reason that under range conditions, horses and cattle, especially, are without an attendant and are often not seen for days or weeks at a time.

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Stockmen are advised to become familiar with the most common poisonous plants, to know the season of the year or other conditions of poisoning, and to herd their animals away from dangerous areas. At the same time, there is some danger in herding animals away from dangerous areas, as many stockmen will testify. Many stockmen who have practiced herding animals from the worst poison-weed ranges, have still suffered heavy losses, and claim to have a smaller loss when the animals are allowed to roam at will and exercise their instinct unmolested in the selection of forage. It is true that the driving of animals to places where there are but few poisonous plants is dangerous under conditions already mentioned, but nevertheless, much may be accomplished in preventing heavy losses by herding animals entirely away from poison-weed areas.

Considering the immense area of grazing lands in the State, and the wide distribution of poisonous plants, their eradication, save in pastures or in certain restricted districts, seems like a hopeless undertaking. Plants that tend to grow more in patches, like the woody aster, monkshood, death camas and false hellebore, promise more in the way of extermination by the use of the grub hoe, than do loco, larkspur and lupine, which are more widely distributed. One instance came under observation in which all the loco weeds on a section of land, under fence, were removed by digging, and three years later the pasture was apparently as badly infested with loco weeds as before, much to the discouragement of the owner. The displacement of noxious weeds and poisonous plants by aggressive forage plants, has received some attention by the Montana Experiment Station and the Forestry Service. For this purpose, the smooth brome grass and the western wheat grass, or "bluejoint," have been considered the most promising. It will require several years at least and much patient endeavor to form a sod with smooth brome grass, sufficiently thick to replace larkspur, camas and loco weeds, which are indigenous and very persistent. The prospect for eradicating poisonous plants by this means is not very encouraging.

ALGAE—GREEN SCUM, GREEN SLIME, WATER MOSS

The algae are simple plants that do not bear leaves, stems, roots, and flowers. Their methods of reproduction are comparatively simple. They are common the world over, living in the water or in very moist situations. The green scum or slime so frequently observed upon the surface of pools, stagnant ponds, reservoirs, ditches, and streams is a growth of algae. Algae also sometimes form heavy growths at the bottom of the water, frequently being attached to stones, sticks, and mud. They are also commonly found in tanks and water troughs, and, in such places, may not only stop up inlet and outlet pipes, but render the water objectionable to stock.

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especially when decay sets in. Decayed algae have a peculiar pig-pen odor.

The common algae found in fresh waters are either blue-green or green in color. Many that occur in the salt water of the ocean are brown or red in color. When the green algae, the forms with which we are most familiar, begin to decay, they may change to brown or reddish-brown.

The individuals of some kinds of algae are microscopic, but when found in mass give a distinct color to the water in which they live. Small pools of water may become greenish in warm weather and on inspection with the unaided eye one is not able to see the organisms causing this coloration. But microscopic examination reveals the presence of millions of small plants.

The question is often asked: Will the green scum found in the watering tank or trough, in water drunk by stock, render the water poisonous? Although algae may give water an objectionable appearance or odor, they do not render it poisonous either to stock or human beings. Furthermore, it is not at all probable that even decaying algae injure the water to the extent of making it poisonous.

However, on account of the objectionable odor that decomposing algae impart to water and on account of their tendency to close up drains and pipes, it is often highly desirable to get rid of them. Algae are now quite easily prevented from growing in water by treatment with copper sulphate.

Eradication.—Use 1 part of copper sulphate (blue vitriol) in 1 million parts of water. Practically, this treatment is best effected by placing a few pounds of the crystals of copper sulphate in a gunny sack, tying this behind a boat and rowing about the pond or reservoir. Fifteen pounds of copper sulphate to 1 million gallons of water is a practical proportion. In the case of a water trough, through which water is steadily running, a small sack of copper sulphate suspended near the inlet will suffice to kill all green scum. If the water in the trough is not freely running in and out, the suspension, in the water of a small sack of blue vitriol for a short time now and then throughout the season will keep green scum from collecting. The small quantities of sulphate that go into solution are harmful to the algae, but do not injure livestock or human beings.

FUNGI

The fungi are an immense group of plants that vary widely in shape, size, color, and habits of living. They do not have roots, stems, leaves, flowers, and seeds. They are rather simple in structure and methods of reproduction. Probably the best known fungi are the molds on bread, fruit and cheese, the rusts and smuts of the cereals, the toadstools and mushrooms, the mildews, and the fungi

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causing such well-known diseases as blight in potato, alfalfa leaf spot, leaf spot of strawberry, potato scab, leaf spot of beet, wilt of flax, etc.

Some of the fungi work on the outside of the plant they infest, while others do their injury within. In most cases, the conspicuous part of the fungus is the spore-bearing stage.

Poisoning by Fungi.—Many plants of this group are poisonous for animals. There is a disease which has been variously named by different investigators, practitioners and others, as food poisoning, forage poisoning, mold poisoning, blind stagger, sleepy stagger, cerebrospinal meningitis, etc., that has been known for a century at least and has caused widespread devastation among animals. The so-called "Kansas Horse Plague" has been quite generally attributed to forage poisoning.

Sporadic cases of this disease are very common in all parts of the United States and at all seasons of the year.

Symptoms.—The first symptoms noticed by the casual observer are depression, drooping of the head, closing of the eyes, difficulty in swallowing, staggering gait, walking in a circle and in some cases pushing the head against the manger or a post. Paralysis follows and the animal finally goes down, and dies within a few hours, or in some cases may live for several days.

Prevention.—The fact that an animal has had the disease does not protect it from a subsequent attack. It should be an absolute rule among farmers and stockmen to *never feed decayed, moldy or spoilt food to animals.* Moldy ensilage, decayed potatoes, carrots, sugar beets, musty hay, and moldy corn stalks are especially dangerous.

Prevention is difficult in those cases that occur on the open range or in grass pastures. The poisoning is presumably from fungi that develop on the grasses under certain climatic conditions. In these cases animals should be taken immediately from the pastures and fed hay that was cut the previous year or earlier in the season.

Treatment.—Many animals that would otherwise die may be saved by appropriate treatment. The services of a competent veterinarian should be sought without delay. Do not try to give any medicine by the mouth for the reason that the throat is paralyzed and the substances, especially if a fluid, will be liable to pass into the lungs and kill the animals. Hundreds of horses were killed in this way during the Kansas outbreak.

MILDEWS

There are two groups of mildews, the *Downy Mildews* and the *Powdery Mildews.* The downy mildews form a downy, white growth upon leaf, stem, and fruit surfaces. One of the most common downy mildews to be found in Colorado on cultivated plants is

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that growing on alfalfa. Many native plants are infested with these fungi.

The powdery mildews are parasitic fungi, very common on the leaves of many cultivated and wild plants. The growth at first has a cobwebby appearance; later, the leaf becomes powdery, due to the production of great numbers of reproductive spores. Still later in the season, fruiting bodies come on the infested plant; these are in the form of black dots, a little smaller than a pin head. Common powdery mildews are those found on the gooseberry fruit, peach, rose, peas, wild and cultivated grasses, and other forage plants. Moist meadows are frequently badly troubled with a powdery mildew. This may be observed to form a white, mealy coating on the leaves. Warm, moist weather favors the development of the mildews.

Poisoning by Mildews.—According to Dr. Pammel, in his "Manual of Poisonous Plants", catarrhal stomatitis (sore mouth) may be produced by eating fodder which has become infested with various fungi, including mildew. The extent to which the mildews are poisonous has never been determined, but they are generally accused of causing inflammation of the digestive tract and other serious digestive disorders.

SMUT

This is a large group of well-known fungi. The best known are those occurring on the cereals. Among these may be mentioned corn smut, stinking smut, or bunt, and loose smut of wheat, loose and covered smuts of barley, loose and kernel smuts of oats, kernel and head smuts of sorghums. Besides these well-known smuts on cereals a number occur on native plants, including grasses and other forage plants. Among these may be mentioned the smut on brome grasses, barnyard grass, Indian millet, manna-grass, squirrel-tail grass, wild rye-grass, fescue grass, hair-grass, slender wheat-grass, etc. Buffalo-grass and grama-grass, the two most abundant and important forage grasses of the Great Plains, are each infested with a smut. These smuts may become very abundant in seasons favorable to their growth. They are especially noticeable in spring and early summer. Hence it is seen that smuts, as a group, are widely spread throughout the State, occurring on both cultivated and wild plants.

Smuts are conspicuous on account of the black, dusty spore masses, which, as a rule, break out on the flowering heads, but also frequently on leaves and stems. A single smutted corn or sorghum plant may produce tremendous quantities of dry, black spores.

Poisoning by Smuts.—It has been a common belief for many years that smuts are injurious to livestock. Feeding experiments, however, have demonstrated that no bad results follow from cattle

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eating any of the smuts. Of course, they may cause a sore throat or irritation of the throat when administered in large quantities, but the injury is not fatal. Furthermore, there seem to be no ill effects resulting from feeding siloed smutty grain or forage.

RUSTS

The rusts are an exceedingly large and widely distributed class of fungi. The best know are those on cereals. There are rusts on wheat, oats, barley, rye, and corn.

Any number of cultivated and native plants, many of which are grazed, are the home of rusts. Common forage grasses that are frequently rusted are timothy, orchard-grasses, fescue-grasses, brome-grasses, wheat-grasses, rye-grasses, marsh-grass, squirrel-tail, salt-grass, grama-grass, wire-grass, and many others; in fact there are but few grasses that are not infested more or less with some rust. There are also rusts on peas, vetches, beans, clover, alfalfa, and a great many of the herbaceous plants that may be eaten by stock. Hence it is readily seen that rusts are common everywhere and on a great variety of plants. And it is quite certain that stock eat considerable quantities of the fungus in their grazing and feeding.

Injury from Rusts.—Rusts no doubt cause considerable irritation of the mouth and the digestive organs and when eaten in large quantities give rise to a catarrhal condition or even severe inflammation. Rusty clover and alfalfa are especially objectionable. Rusts, as a group, are not poisonous.

MOLDS

Many fungi are known by the name of "mold." Well-known ones occur on fruit, bread, and cheese. A bluish-green moldy growth develops on hay, ensilage, fodder, and the kernels of corn, barley, and other cereals, usually when they are cured or stored under moist, warm, or poorly-aired conditions.

Poisoning by Molds.—Some of the molds are very poisonous and others are not. The inability to tell which molds are poisonous should make one cautious about feeding moldy foods of any kind. Poisoning by molds was discussed on a previous page under the subject of fungi.

ERGOT (*Claviceps purpurea*)

Ergot is a name applied to one stage of a fungus working in the heads of a number of grasses. The ergot stage is a purple-black. straight or horn-like hard structure about one-fourth to one-half inch long (Fig. 1). It occupies the position of the grain in the head of grass. This hard mass is not a degenerate kernel of grass, however. During the fore part of the growing season, the young and tender ovaries of the grass flower are infected with spores of the fungus, which later develops into the ergot stage. As a result of this infection, a fungus growth covers and penetrates

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Fig. 1. Ergot: Note the black, horn-like bodies occupying the position of the grain. Ergot is shown here on six different grasses, cultivated rye at the left, the remainder native forage grasses.

the young grass ovary, finally replacing the latter entirely with fungal tissue. Minute spores are then produced in large numbers, and carried to other plants by means of insects and wind. In this way the disease spreads throughout the field. In the latter part of the summer the soft, fungous mass in the head of grass is replaced by the characteristic hard, black structure, commonly known as ergot (Fig. 1). This is the structure by means of which the fungus lives over the winter. The black ergot masses vary in size and shape, depending upon the plant attached. They are the largest on rye.

Ergot develops upon a number of grasses. Chief of these is cultivated rye (*Secale cereale*) and various species of wild rye (*Elymus*). It also occurs on several wheat-grasses (*Agropyron*), a number of meadow grasses (*Poa*), timothy (*Phleum pratense*), a reed canary-grass (*Phalaris arundinacea*), prairie June-grass (*Koeleria cristata*), and several other grasses.

Ergot is widely distributed throughout this country and Europe. It does but little injury to the grass upon which it is living, but is often the cause of serious troubles in livestock.

Ergotism.—Ergotism is the disease caused from eating grasses that contain ergot. Cattle are most often affected. The disease makes its appearance most often during the winter and spring but may appear at any time.

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Symptoms.—Two distinct types of the disease are recognized, namely, spasmodic and gangrenous. There are serious digestive disturbances in both types of the disease.

In the spasmodic form, there are spasmodic contractions of the muscles, numbness of the extremities, tremblings, convulsions and delirium. In the gangrenous form of ergotism, there is, as a result of prolonged constriction of the blood vessels, especially of the extremities, a decreased amount of blood to the parts, and in some cases the circulation is completely obstructed. When the circulation is obstructed, dry gangrene follows and there is sloughing of the tips of the ears, tail, hair, and even the feet may come off as far up as the canon bones. Cold weather, of course, helps to make conditions worse.

Treatment.—In the first place, remove the cause. Examine the hay for the black ergot bodies which grow in place of the kernels of grain in the heads. Treatment is not very satisfactory in well established cases. Tannic acid is the best chemical antidote and its effect is upon the poisons that are not yet absorbed into the circulation. Chloral is probably the most satisfactory physiological antidote. Animals affected with ergotism should be kept warm and treatment should be directed to meet the conditions as they arise.

"TOADSTOOLS" AND "MUSHROOMS" (*Fleshy Fungi*)

There are a great many different sorts of fleshy fungi that are called "toadstools" and "mushrooms," depending upon whether they are considered poisonous or edible. Although a number of these fungi poison human beings, it is doubtful if stock ever eat them.

BLACK SPOT OF GRASSES (*Phyllachora graminis*)

In late summer and fall, there appear on the leaves of several of our forage grasses, jet black spots, especially noticeable along the veins. These spots are very small, scarcely larger than a pin-head, and occur on both surfaces of the leaf, although more abundant on the upper. In Colorado, "black spot" is found on several different forage grasses. It may be the cause of a stomach inflammation in stock.

LICHENS

The most common lichens (Fig. 2) are those forming crust-like coverings on the surface of rocks, or tree trunks, or on the ground. Some are raised considerably above the surface upon which they grow, and are leaf-like. There is a form of lichen in our mountains which hangs in gray-green, moss-like masses from the branches of the evergreens. Lichens have a great range of color: Orange, yellow, green, gray, brown, and black. They are composed of certain algae and fungi growing in intimate relation-

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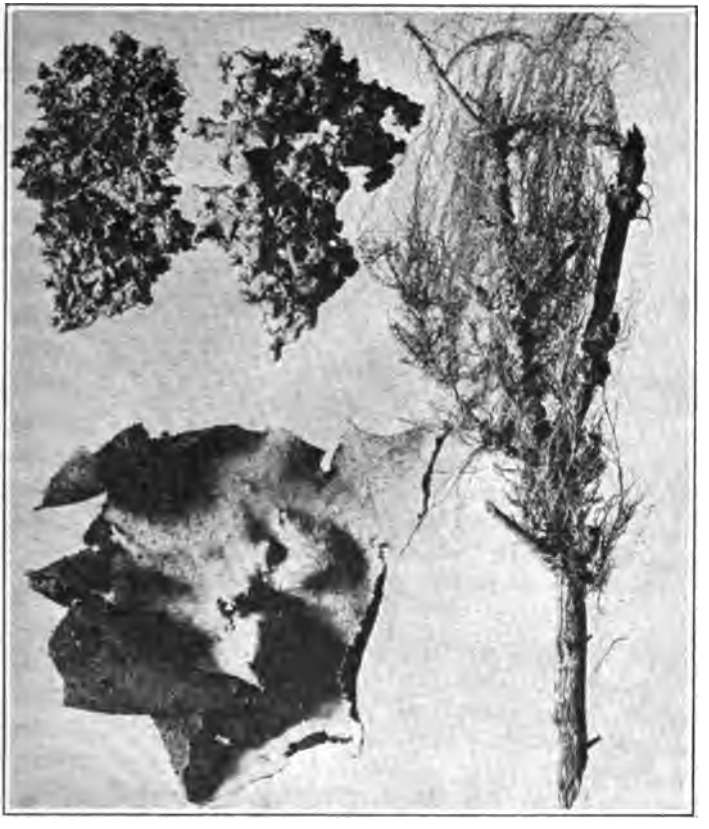

Fig. 2.—Four different lichens

ship. Lichens, as a group, withstand drying very well, and have remarkable powers of recovery when moisture becomes available

None of the lichens are known to poison stock. It is quite likely that some of the leafy sorts are eaten to a slight extent.

MOSSES

Mosses are familiar to all. They are not as abundant under the dry atmospheric conditions of Colorado as in moister sections of our country. They are the best developed in the mountains, especially along streams and in shaded situations. None of the mosses are known to be, or suspected of being, poisonous to stock.

FERNS

Colorado does not possess a large variety of ferns; furthermore, they do not grow in such luxuriance here, as in the damp, moist woods of the eastern states.

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Figs. 4-5—Brake-fern (*Pteridium aquilinum*): 4, single pinna of leaf of brake-fern, showing the spore masses on the under surface; 5, single leaf of brake-fern.

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Ferns have underground stems that run horizontal to the soil surface. They spread by means of these stems, and also by means of spores. The spores are formed on the under side or margin of the frond (leaf). These spores occur in reddish-brown masses (Fig. 4).

The only fern in Colorado that is suspected of being poisonous to stock is the brake-fern (*Pteridium aquilinum*) (Fig. 5). This plant has widely-spreading, blackish rootstocks. The leaves are two to three feet long, and divided into three main divisions, each of which is again subdivided.

EQUISETUM—HORSETAIL, SCOURING RUSH, JOINTED GRASS

There are several species of Equisetum growing within Colorado. The two most common ones are the Common Horsetail (*Equisetum arvense*), and the Smooth Scouring Rush (*Equisetum laevigatum*). Both are rush-like perennials from underground rootstocks. They have rough, jointed stems that are closed at the joints. The stems are marked with a number of grooves that run lengthwise. At the joints are small, pointed, leaf-like structures, the sheaths. All horestails and scouring-rushes have harsh, rough stems, due to deposits of silica (sand) within.

The common horsetail (Figs. 6 and 7) (*Equisetum arvense*) dies down to the ground each year. It has two kinds of stems. In the early spring there are sent up from the underground rootstocks, simple, unbranched, jointed stems, which bear a spore-bearing cone-shaped organ at the top (Fig. 6). These die down after spore production, and are followed by slender, solid, 4-cornered stems that send out numerous branches at the joints (Fig. 7). The common horsetail is found throughout the State, from the plains up to as high as 10,000 feet. It commonly grows in sandy places, along railways, roadsides, and in low meadows. In meadows, it may become so abundant as to injure the hay. It is here that it gives the greatest amount of trouble.

The smooth scouring rush (*Equisetum laevigatum*) is evergreen. The stems are stout and often reach a height of 5 feet. They may be branched or unbranched. This plant grows all over Colorado from low to high altitudes. It is also found in low ground, particularly in a clay soil.

Poisoning by Equisetum.—Equisetum is so abundant that most people do not suspect that it is poisonous. It is found in much of the native hay of Colorado. Many reports have come to the Experiment Station of serious poisoning of animals that could only be attributed to horsetail. We have never had reports of animals other than horses being affected.

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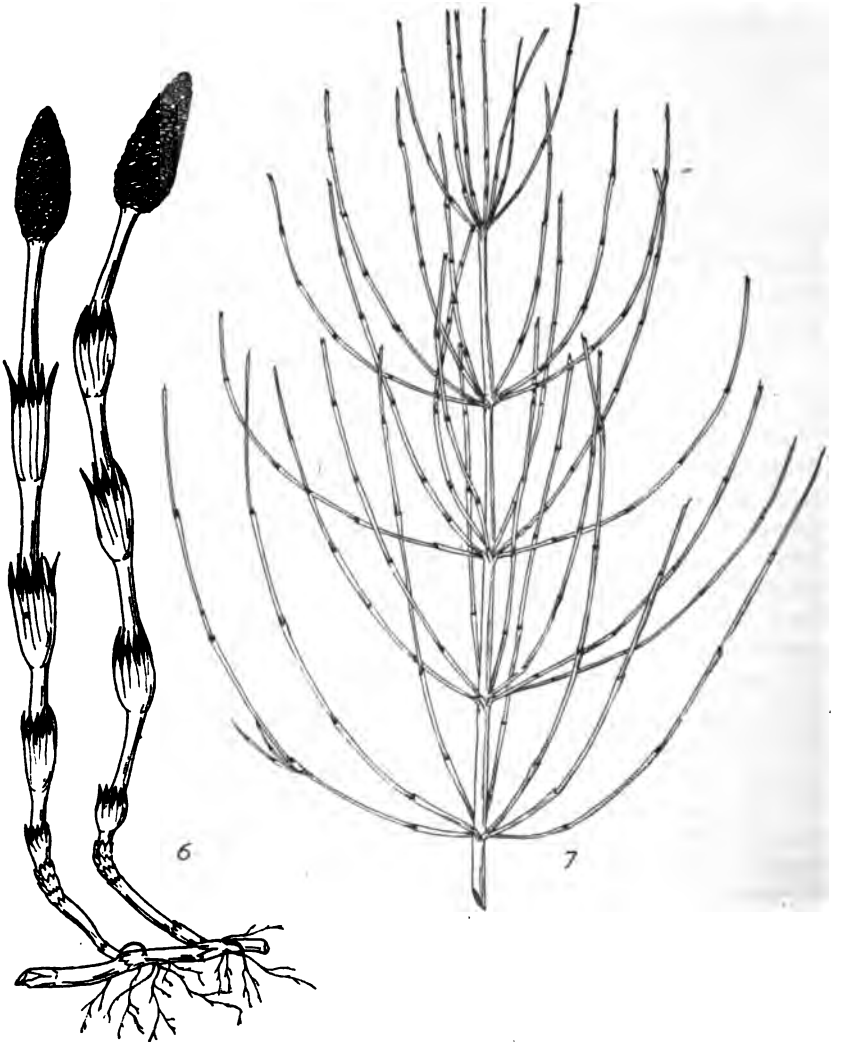

Figs. 6-7.—Horsetail or scouring rush; 6, early spring stems arising from underground stem; note fruiting cones; 7, branching form which appears later than the preceding.

Symptoms.—The first evidence of the trouble is more or less unthriftiness and in most cases diarrhoea. The horse appears thin and the muscles wasted. After two to five weeks, according to the amount of horsetail in the hay, the horse begins to lose control of its limbs, sways and staggers, although its eyes look bright and the appetite is normal. After the muscular symptoms become pronounced the horse will refuse to lie down and if it gets down will

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struggle violently to get to its feet. The extremities are cold, and horses that are affected from eating Equisetum suffer greatly from the cold in the winter time. Young horses develop the symptoms much quicker than older ones. Some claim that horses develop a depraved appetite for the weed.

Treatment.—Stop feeding the Equisetum hay and give a quart of raw linseed oil as a physic. After the physic has operated give a teaspoonful of powdered nux vomica, mixed with the feeds of grain, three times a day. If the horse becomes very weak, he should be supported by slings. These cases, if given prompt attention and an appropriate treatment, will recover in most instances.

EVERGREENS (*Conifers*)

The pines, spruces, firs, junipers and cedars are widely distributed over Colorado. They have not been known to poison stock.

CAT-TAIL (*Typha latifolia*)

This common plant, found in marshes at lower altitudes in Colorado, is suspected of being poisonous.

GRASSES

A number of grasses are known to poison stock, while others injure them mechanically by means of their sharp beards or bristles.

Grasses are closely related to, and frequently mistaken for, sedges. Sedges, however, have solid stems, usually 3-cornered. They prefer, as a rule, moister situations than grasses.

POISONOUS GRASSES

JOHNSON GRASS (*Andropogon halapensis*)

This is a perennial from rootstocks. The plant is from 3 to 5 feet tall. The leaves are broad, flat and smooth. The inflorescence or flowering head often measures 1 foot or more in length, and branches profusely. The spikelets are in pairs; one of these has a short stalk, the other is without. The spikelets are covered with long, soft hairs, and are often purplish in color when mature. A beard may be present or absent.

Johnson grass has been reported from several localities in Colorado. In some places it is cultivated, and from such it may escape and become a weed.

Johnson grass is undoubtedly poisonous under certain conditions. Discussion of this subject will be found under the head of Sorghums.

SORGHUMS (*Andropogon sorghum*)

The sorghums comprise a large and well-known group of plants that are used both for their grain, and as hay and fodder. Under the name "sorghum" are included sweet sorghum or sorgo, milo, durra, kafir, broom corn, kaoliang, shallu, feterita, and Sudan

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grass. All are annual plants, ranging in height from 3 to 15 feet. The "heads" vary considerably in size, shape and color.

Poisoning by Sorghums.—A large number of plants are known to be poisonous from the presence of prussic or hydrocyanic acid. This acid is known to be one of the most deadly poisons, and it results from the presence in the plant of what is known as a glucoside, which must be acted upon by a ferment. The most important and best known of all the glucosides is amygdalin. A large number and a great variety of plants contain a hydrocyanic acid producing glucoside. Plants that are conspicuous in this class are sorghum, kafir corn, Johnson grass and wild cherry.

Conditions Under Which Poisoning May Occur.—The second growth of sorghum is generally accused of being the more dangerous, but in the late summer, when the second growth appears, the entire plant contains poison. Kafir corn is the least dangerous when grown luxuriantly under irrigation or bountiful rainfall. The conditions which prevail in the arid districts of Colorado are ideal for growing kafir corn that is most dangerous. When kafir corn has made a stunted growth, and in the fall for two or three weeks before frost, the most poisoning occurs. After it has been cured from cutting or frost, it has never been known to kill animals, unless it be later demonstrated that hydrocyanic acid is a causative factor in "Corn Stalk Disease."

The leaves of several species of wild cherry are very deadly to cattle. The special condition under which wild cherry poisons animals is when the leaves are partially wilted.

The poison in question has been found in a great number of both native and domesticated plants and it is quite possible that in many cases where a large number of animals have died mysteriously, without the presence of either infection or any known poisonous plant, that some plant capable of developing prussic acid is responsible.

Symptoms.—A few mouthfuls of highly poisonous kafir corn taken on an empty stomach have been known to kill a cow in ten minutes. At Brighton, Colorado, 32 cows, after being kept in the corral over night, were turned into a field of kafir corn of not over 2 acres, that had been grown above the ditch, and 21 of them were dead in half an hour and four of the others were badly affected.* The first thing noticed in a poisoned animal is giddiness and difficult breathing, with spasmodic defecation and micturition. The pulse is slow and the pupils dilated. In fatal cases this is followed by spasms, general paralysis, delirium and death. In subacute cases the above symptoms will appear in a milder form and the animal may regain consciousness and be on its feet in an hour or two.

*Bulletin No. 77, Nebraska Experiment Station.

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Treatment.—Farmers should know the conditions under which the plants mentioned are liable to kill their animals, and take no chances. Acute cases are so rapidly fatal that the animal is often dead before remedial measures can be adopted. In case of poisoning by prussic acid in connection with forage, however, the symptoms usually do not develop so quickly and some assistance may be given. Inhalation of ammonia and throwing alternately cold and warm water over the head and neck have been advised. Hypodermic injections of atropine sulphate to stimulate the heart and respiration are indicated. The chemical antidote (which must be given before the poison is absorbed) is a mixture of ferrous and ferric salt, administered with magnesia or potassium carbonate in solution.

MILLETS

The proso, or broom corn millet, foxtail millets and pearl millet are the principal ones grown. The foxtail millets (*Setaria italica*) are divided into a number of types, chief of which are the Hungarian, German, Common, Golden Wonder, and Siberian. All are annual.

MECHANICALLY INJURIOUS GRASSES

SAND-BUR (*Cenchrus tribuloides*)

The common sand-bur (Fig. 8) is an annual grass with flat leaves. The long stems may be prostrate on the ground for a part of their length. The characteristic feature of the plant is the spiny structure surrounding the spikelet. As a consequence, there is formed a spiny bur, the spines being stout and barbed. There are as many as 20 burs in an inflorescence. The seed matures from July to September. Sand-bur is found growing in sandy soil, as a rule. It occurs throughout Colorado, at lower altitudes.

POVERTY-GRASS, WIRE-GRASS, THREE-AWNED-GRASS (*Aristida longiseta*)

This is a tufted, silvery-colored perennial with numerous rolled, wire-like leaves at the base of the plant. Its common height is about 1 foot. There are some varieties that are much more robust, however. The flowering head is 4 to 8 inches long. The spikelets are small and 1-flowered. The grain is tipped by three beards or awns (Fig. 9), thus suggesting the common name "three-awned-grass." The lower end of the mature seed is very sharp-pointed.

Wire-grass is one of the chief grasses of the Great Plains. In certain places in eastern Colorado it forms an extensive growth. It is also found on dry hills, up to an altitude of 9,000 feet.

FEATHER-GRASS, PORCUPINE-GRASS, OAT-GRASS (*Stipa*)

There are a number of different Stipas growing in Colorado, all of which are tufted perennials The leaves are usually rolled.

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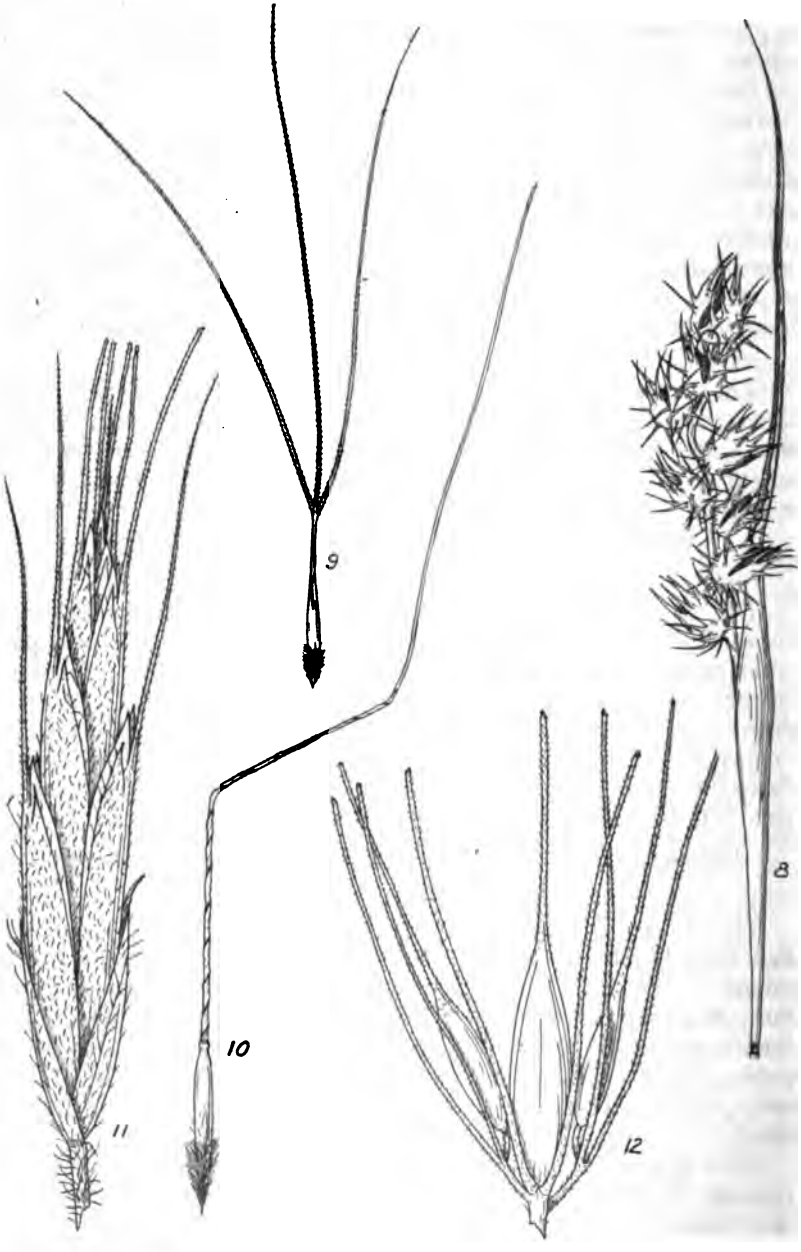

Figs. 8-12.—Mechanically injurious grasses; 8, sand-bur; 9, grain of three-awned grass; 10, grain of porcupine grain, showing long, twisted beard; 11, spikelets of downy brome-grass; 12, triplet of spikelets of squirrel-tail grass.

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The inflorescence branches. Each spikelet produces one seed which falls at maturity from the flowering head. Each grain bears a long beard (Fig. 10), which is twisted at the base, where it joins the body of grain, and is more or less bent. The base of the grain is very sharp-pointed, and the small barbs on it point upward. Hence, the grain may work inward easily, but on account of the direction of the barbs, it is impossible for it to work outward, or to be pulled out easily. It matures its seed from July 15 to August 15. The mature seed immediately drops to the ground.

The Western Stipa, or needle grass (*Stipa comata*) bears beards that reach a length of 4 to 6 inches. This grass is abundant in sandy soil throughout the plains and foot-hill regions. There are a number of other species of Stipa, which differ from needle grass in having beards usually less than 2 inches long. In these, also, the beards are twisted and bent, and the grain-base is sharp-pointed, and may in some instances work mechanical injury to stock. One of the very common short-bearded Stipas is Vasey's Stipa-Grass (*Stipa vaseyi*). It is particularly abundant in the foot-hills. It grows from 3 to 6 feet high and bears an inflorescence 8 to 18 inches long. The beard on the grain is usually bent twice, and twisted to the second bend.

WILD OATS (*Avena fatua*)

This is an annual plant much resembling ordinary cultivated oats. It has long, slender stems, and hence it usually stands above cultivated oats. It is distinguished further from cultivated sort by its strongly bent beard, and the long, reddish-brown hairs at the base of the grain. The seeds ripen earlier than those of wheat and oats. The seed is barbed.

DOWNY BROME-GRASS, AWNED BROME-GRASS, SLENDER CHESS (*Bromus tectorum*)

This brome-grass is an annual. It stands 1 to 2 feet tall. The leaves are soft hairy. The flowering head has slender, drooping branches. The spikelets (Fig. 11) are on very thin stalks; they bear a number of seeds. They may become purplish at maturity. Each seed has an awn which equals the seed itself in length.

This plant is becoming increasingly abundant in Colorado, occurring in fields, along roadsides and in waste places. In many localities it has made its first appearance the last year or two. Up to now it has been seen only at lower altitudes.

The beards on the seeds frequently cause serious injury to stock. The bearded seeds work in under the teeth causing inflammation, and in some instances a loss of the teeth.

WILD BARLEY, SQUIRREL-TAIL GRASS (*Hordeum jubatum*)

In the West, this common grass is an annual or short-lived perennial. It grows from 6 inches to 2½ feet high, in bunches.

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The head is 4 inches long or less, pale green, often purplish. The beards on the seed-bearing, and sterile flowers are long, and the flowers are surrounded by long, beard-like glumes so that the whole head is covered with long bristles (Fig. 12) that are rough and upwardly barbed. The head breaks up at maturity and the parts are scattered broadcast.

Squirrel-tail grass is common in alkaline soils, about ponds, lakes and reservoirs, along irrigating ditches and streams, in meadows, and in fields wet from seepage. It is a common sight in Colorado to see ponds and lakes surrounded by a well-marked zone of squirrel-tail. Squirrel-tail grows over the entire State up to as high as 9,000 feet.

The plant is not only troublesome as a weed in cultivated fields but it is a great source of injury to stock. Although it may be eaten by all classes of stock when young, when mature the awns have very injurious effects.

Wind is the chief agent in the dissemination of the seed, but in the irrigated sections its spread by water is common. Plants growing on the banks of irrigating ditches drop their seed into the running water, which carries them to fields where they are distributed over the land. Every precaution should be made to prevent the seeding of squirrel-tail along ditches. If possible, mow the infested area several times during the season to prevent seeding.

Mechanical Injury from Grasses.—As a group, the mechanically injurious grasses frequently inflict serious wounds. The beards may bore into the skin, or the mucous membrane of the mouth, causing ulcerations. They have been known to bore into the intestines, causing fatal inflammation. The beards of Stipa grasses are reported as injuring the eyes of sheep. Sheep have also been known to die from body wounds inflicted by the beards of grasses. In some instances the beards work in under the teeth, causing inflammation and the formation of pus. As a result, the animal may lose its teeth. Ulcerations of the jaw bones sometimes follow.

DEATH CAMAS (*Zygadenus*)

There are several species of death camas growing within Colorado. The following description is made general enough to include all of them. There is no attempt to distinguish between the different sorts, for such a distinction is of no advantage, in this case, to the practical man.

The plants are perennial from a bulb (Fig. 13). This bulb is made up of a series of layers, like the onion, the outer ones being thin, blackish-brown, and peeling off, showing the white-colored layers beneath. The bulbs are, as a rule, very deep-seated, so much so that it is difficult to get them up without breaking the stem. An average size bulb is about 1 to 1½ inches long and ½ to 1 inch

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Figs. 13-14.—Death camas: 13, entire plant; 14, fruiting stalk.

thick. It tapers above into the solid stem. A tuft of roots arises from the under side. Plants vary in height from 8 inches to 2 feet. They are smooth throughout, no hairs or bristles being present. The leaves are long, narrow, and more or less folded along the midrib; they resemble those of the onion. There are usually six to seven fully formed leaves on a plant. The flowers are at the tip of the stem, in an inflorescence 3 to 10 inches long; they are greenish-yellow or whitish in color. Each flower (Fig. 15) has six segments, about one-half inch long; at the base of each segment on the inner surface is a golden yellow, shining gland, which may be seen without the aid of a hand lens. The lowermost flowers mature their fruit first, in fact there may be flowers and fruit in the same flowering group. The fruit (Figs. 14 and 16) is usually 3-parted, the separate parts united except at the very tip.

Considering the different species found in Colorado, death camas occurs throughout the whole State, from low to high altitudes. There is some evidence that plants growing at high altitudes belong to a species that does not contain as much of the poisonous principle as plants at lower elevations.

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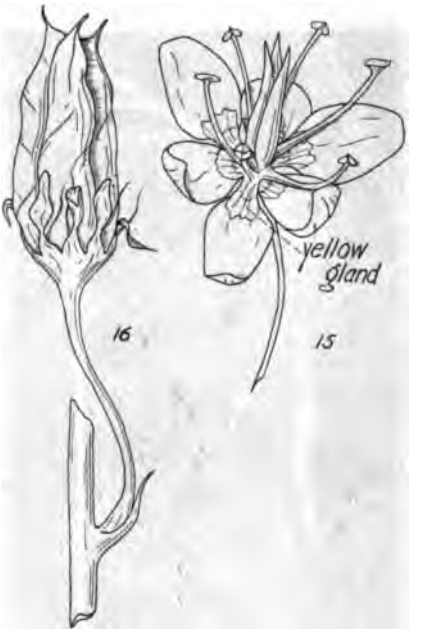

Figs. 15-16.—Death camas: 15, single flower, showing three sepals, three petals, six stamens, one pistil, and yellow glands; 16, single pod.

Death camas makes its appearance in the spring and early summer. At lower altitudes the flowers are in bloom during June. During maturing of fruit, the flower stalk may lengthen considerably. It is abundant in the foot-hills, sometimes on stony hillsides, also on sandy plains, but more abundant in moist, sandy swales. As a rule they do not form a close stand; the individual plants are rather scattered.

Death camas may be confused sometimes with several other plants. One of these is the white hellebore (*Veratrum speciosum*) (Fig. 17). It has rootstocks instead of bulbs, the leaves are large and oval and clasp the stem, and there are no glands at the base of the petals and sepals of the flower. Another is the spiderwort (*Tradescantia*), which has leaves very much like those of death camas, but no bulb; the flowers are blue and much larger. Another is the sand-lily (*Leucocrinum*), a low plant, close to the ground, with large white lily-like flowers. The wild onions, of which there are a number of species, are most frequently mistaken for death camas. They have bulbs and leaves that are similar to those of death camas. However, the odor of the wild onion should be sufficient to distinguish it from the death camas. The flowers are arranged quite differently in the onion as may be seen readily by comparing Figs. 13 and 18. Occasionally, the mariposa lily

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(*Calochortus*) is mistaken for death camas. In this, the underground stem is a corm, that is, a solid structure, not made up of layers. Furthermore, the flowers are few in number, large, and showy.

Symptoms of Poisoning.—The symptoms of poisoning by camas are quite characteristic and one should be able to recognize these cases with a considerable degree of certainty. At first the animal is uneasy, and an irregularity of the muscular movements of the body is apparent. This is followed by complete loss of muscular control, rapid and difficult breathing, spasms and a frequent but weak pulse. The one condition that especially characterizes poisoning by death camas is the complete muscular paralysis without loss of consciousness.

Preventive and Remedial Measures.—There is only one way to prevent poisoning by death camas and that is to keep animals away from it. It is then of first importance that stockmen be able to identify the plant. It is first seen in the spring about the same time as the first green grass and dries up and disappears in middle summer. Its close resemblance to wild onion will help some in its identification.

Treatment.—The treatment that has given the best results is potassium permanganate. Chestnut and Wilcox report, as a result of their experiments, that it is effective both as a chemical and physiological antidote. For sheep, three to six grains, according to the size and age of the animal, of potassium permanganate and an equal weight of aluminum sulphate are dissolved in at least a pint of water and given at one dose by drench. Twenty grains of each dissolved in a quart of water constitute a dose for an average-sized horse, and 30 to 50 for cattle.

It is very important that all of the potassium permanganate be dissolved, otherwise flakes may adhere to the walls of the throat or stomach, and cause intense irritation. Some stockmen make a practice of carrying this antidote in their saddlebags, ready for immediate use, during the spring months when there is the greatest danger of poisoning from camas. This practice is to be recommended, since the antidote is equally effective for poisoning by larkspur, and larkspur and camas are most dangerous at about the same time in the early spring months.

WHITE HELLEBORE, FALSE HELLEBORE

(*Vertrum speciosum*)

This perennial (Fig. 17), from a thick rootstock, grows from 2 to 7 feet high. The leaves are large, broad, and bear prominent veins, running parallel. The inflorescence may be over a foot long. The branches of the inflorescence are directed upward, and each has a long, narrow leaf at its juncture with the main stem. The in-

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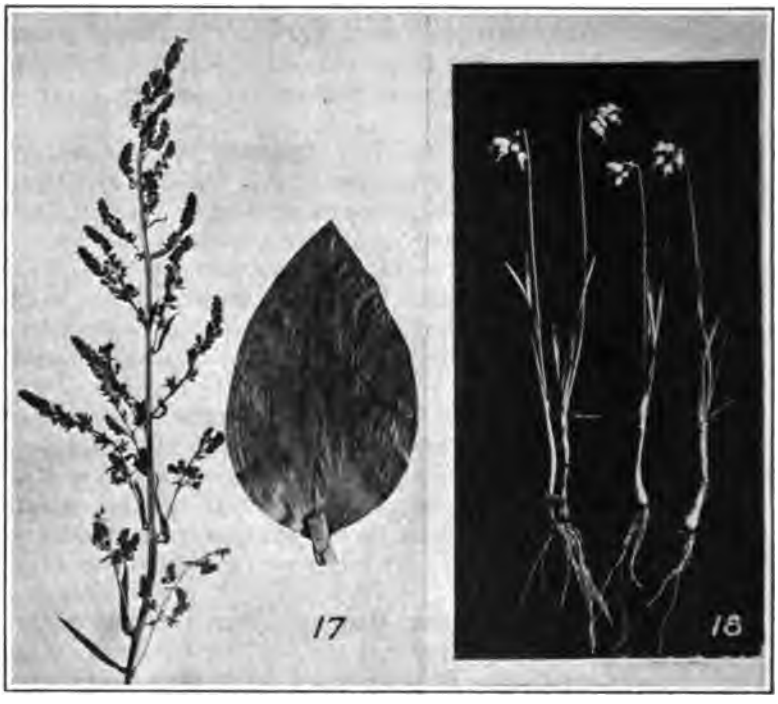

Figs. 17-18.—17, leaf and flowering group of white hellebore; 18, wild onion or garlic, often mistaken for death camas.

florescence is covered with soft, white hairs. The flowers are whitish, each has three sepals, three petals, six stamens and a single pistil. The plant is not abundant in Colorado. It has been observed in a few localities, chiefly in the western half of the State. It occurs from 6,500 to 12,500 feet altitude. It prefers moist soil, such as is found along streams and in meadows.

Poisoning by White Hellebore.—The swamp hellebore is not relished by animals, since it is acrid and bitter, but some cases of poisoning are reported. The seeds have been eaten by chickens with fatal results and a case is reported by Prof. Chestnut in which all of the members of a household were poisoned by eating the young leaves, mistaking them for marsh marigold. The root is said to have been used by the Indians in making snuff.

Symptoms.—Several poisonous substances are found in hellebore. Veratrin, which may be separated into several poisonous bases, causes extreme depression of the heart and respiration and general paralysis. The poisoned animal is first seen drooling saliva, vomiting or attempting to vomit, with colicy pains, shallow breathing; the skin becomes cold and clammy and there are muscular tremors and in fatal cases the animal dies in convulsions.

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Treatment.—This consists in giving tannic acid as a chemical antidote with alcohol, strychnine and atropine to support the heart and respiration. Raw linseed oil may be given to relieve the local irritation and laudanum or morphine to relieve the pain.

SCRUB OAK (*Quercus*)

There are a number of species of scrub oak in Colorado. They are all small trees or shrubs, their common height being 10 to 15 feet. As a rule they grow in rather dense clumps. Scrub oak in Colorado is found in the foothills and mountains of the western slope, and as far north on the eastern slope as an east-west line about midway between Castle Rock and Denver.

Scrub oak is considered poisonous by many stockmen. They will take the pains to keep their stock from the oak thicket. It is very likely that most cases of poisoning resulting from cattle grazing in scrub oak thickets are due to larkspur which grows therein.

GREASEWOOD (*Sarcobatus vermiculatus*)

The common greasewood of the West is a shrub, 2 to 8 feet high. Its numerous branches are very stiff and rigid, and frequently somewhat spiny; the bark is smooth and white. The leaves are thick, narrow, 1 to 2 inches long, and pale green in color. The flowers are small, inconspicuous and greenish.

Greasewood is characteristic of dry, alkali flats. It is distributed throughout the State, chiefly at lower elevations.

It is likely to be confused with several other shrubs: Winter fat or winter sage (*Eurotia lanata*) is a low shrub, coated with a mat of white, woolly hairs which may become reddish-brown. The common shrubby salt-bushes (*Atriplex canescens and Atriplex confertifolia*) are somewhat rigid or spinescent shrubs with smooth, white bark, much resembling greasewood. The leaves of the salt-bushes, however, are covered with minute scales, which give them a characteristic scurfy appearance. Those of greasewood are smooth. Furthermore, the leaves of the two salt-bushes given above are not long and slender, as in greasewood, but rather narrowly oblong in one, and oval in the other. The spiny Grayia (*Grayia spinosa*) also has mealy or scurfy leaves. The shrubby species of rabbit brush (*Chrysothamnus*) may be distinguished from greasewood by their flowers, which resemble those of goldenrod.

Greasewood is considered a forage plant, but is strongly suspected of being poisonous at times. Prof. Chestnut reports on this plant as follows: "A correspondent in New Mexico states that on one occasion he counted as many as one hundred sheep that had been killed by eating the leaves of this plant. It is claimed that cows are not affected by eating it at any time and that sheep can eat it quite freely in winter. Death is perhaps due more to the bloating effect than to any poisonous substance which the plant contains."

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Fig. 19.—Cow-herb, cow cockle, wheat cockle (*Saponaria vaccaria*).

RUSSIAN THISTLE (*Salsola pestifer*)

The Russian Thistle is so well known that a description is unnecessary. In Prof. Pammel's "Manual of Poisonous Plants" is found the following: "The sharp spines on the plants not only irritate and worry both horses and men but often, by breaking under the skin, cause festering sores on the horses' legs, so that in many localities it has been found necessary to protect them with high boots or leggings."

COW-HERB, COW COCKLE, WHEAT COCKLE (*Saponaria vaccaria*)

A smooth, branching annual plant (Fig. 19) 8 to 16 inches tall. The leaves are opposite and lance-shaped. The flowers are a beautiful pink, in open clusters at the top of the plant. The calyx is 5-angled, and much enlarged in the fruit. The plant is a pest in some sections of the State, particularly in grain fields. It is found mostly at low altitudes.

The seeds of Cow Cockle are often found in wheat screenings, and are known to be poisonous. Prof. Pammel says: "According to Sohn it contains the substance *saponin*, a neutral, sharp, amorphous substance, having a burning taste and producing a violent sensation. The toxic substance is partially removed by baking." Saponin-like bodies are also found in the common plant known as "bouncing bet" and corn cockle.

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LARKSPUR (*Delphinium*)

As a group, the larkspurs are easily recognized by the single long "spur" (Figs. 20, 21, 22) of the flower. A single sepal of the flower is prolonged into a spur, and encloses two petals which are likewise extended. Larkspurs may be distinguished from aconite or monkshood, which they closely resemble, by the form of the flower. In aconite or monkshood the upper sepal, instead of being spurred, as in larkspur, is enlarged and has the appearance of a hood (Fig. 23) over the other flower parts, hence the name monkshood. These differences are brought out in the drawings.

A number of native plants are often mistaken for larkspur, especially in the young stage. Chief of these is the wild geranium, of which there are several species within our borders. There are two small leaves (stipules) (Fig. 30) at the base of the geranium leafstalk; these are absent in larkspur. The false mallow (Fig. 31) (*Malvastrum coccineum*), when young, may be mistaken for larkspur. Its leaves are coated with hairs that are in star-shaped groups (Fig. 32). The leaves of the common spring anemone (Fig. 34) (*Pulsatilla hirsutissima*) with lavender flowers, are much more divided and in a fashion different from those of larkspur. The wind flower (Fig. 33) (*Anemone*) has leaves quite similar in shape to those of larkspur but the hairs are longer and more spreading. Both the common spring anemone and the wind flower have a characteristic group of leaves (*involucre*) on the flowering stem (see Fig. 36). In Fig. 35 is shown the highly divided leaf of Virgin's Bower (*Clematis douglasii*) which may be mistaken at times for that of one of the larkspurs. The stockman should thoroughly familiarize himself with the appearance of young larkspur plants.

There are a number of species of larkspur growing in Colorado, the principal ones being as follows: Purple, or Nelson's larkspur (*Delphinium nelsonii*), Geyer's larkspur (*Delphinium geyeri*), Penhard's larkspur (*Delphinium carolinianum penhardii*), subalpine larkspur (*Delphinium subalpinum*), and tall larkspur (*Delphinium glaucescens*).

Purple, or Nelson's Larkspur (*Delphinium nelsonii*). The easily detachable cluster of thickened tuberous roots (Fig. 38) is characteristic of this species. The plant (Figs. 27 and 37) rarely exceeds 2 feet in height; about 1 foot is its common height. The leaves are divided into a large number of narrow segments. The flowers are blue, the two petals, not prolonged as spurs, each have a cobwebby tuft of white hairs in the center of the broad blade, on the outer surface. The fruit (Fig. 24) may be smooth or hairy.

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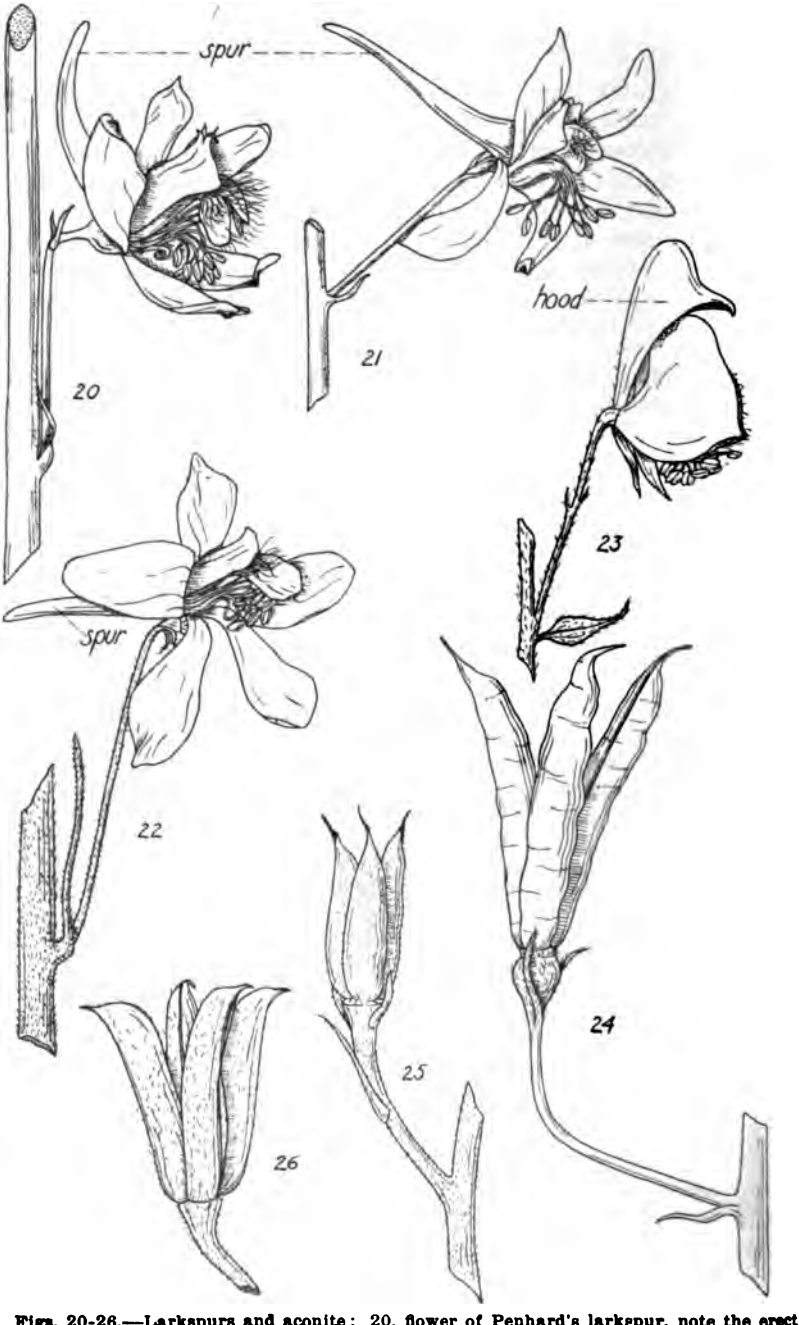

Figs. 20-26.—Larkspurs and aconite: 20, flower of Penhard's larkspur, note the erect flower stalk and spur; 21, flower of Nelson's larkspur; 22, flower of Geyer's larkspur; 23, flower of aconite; note the "hood"; 24, fruit of Nelson's larkspur; 25, fruit of Geyer's larkspur; 26, fruit of aconite.

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This species is the earliest of the larkspurs. It may be seen in bloom as early as April 20 at low altitudes. In the foothills it is usually past blooming by June 1.

Its altitudinal distribution is from 4,000 to 10,000 feet. It is found all over the State within these limits.

Geyer's Larkspur (*Delphinium geyeri*) (Figs. 28 and 40).—This is a taller plant than the preceding, ranging in height from 10 inches to over 2 feet. The root is thickened and somewhat woody. There is a cluster of thick, dull-green leaves at the base of the plant; they are cut into numerous long, narrow segments, each segment being tipped with a white, hardened point. The flowers are blue.

This larkspur is a plant of low altitudes, seldom growing above 7,000 feet. It blooms during the first part of July.

Penhard's Larkspur (*Delphinium carolinianum penhardii*).—(Fig. 39). This species grows to about the same height as the preceding, and may often be found alongside it, occupying the same sort of habitat, and in bloom at the same time. The flowers are usually white, sometimes light blue or greenish white. The spur commonly points upward, being parallel with the main stem. The petals are covered with long, soft hairs.

Subalpine Larkspur (*Delphinium subalpinum*).—This larkspur has a large woody root, and frequently grows to a height of 4 or 5 feet, although it may be much smaller. The leaves are not as finely divided as those of the three preceding species; they are divided into about five main divisions, each of which is further divided. The inflorescence also differs from the preceding, being dense and short, rather than loose and lengthened. The flowers are very deep blue. The fruit is short and smooth.

This is a plant of high altitudes, frequent at 10,000 to 11,000 feet, but often found as low as 8,000 feet, and above timber line. It is found in moist, rather shady situations and forms characteristic, large, dense beds.

Tall Larkspur (*Delphinium glaucescens*).—In this, several stems arise from a thick, woody root. The plant stands 1 to 5 feet high. The large leaves, 2 to 6 inches in diameter, are divided into five to eight wedge-shaped main divisions, each of which is further divided, usually into three segments. The pale blue flowers are in a rather short, loose cluster. The fruit is hairy. The tall larkspur is found mainly in the mountains, from 7,000 to 9,000 feet, in moist places.

Poisoning by Larkspur.—There can be no question that in the mountainous districts of Colorado the several species of larkspur cause a greater loss to stockmen through poisoning than all other poison weeds combined. Laboratory experiments indicate that the different species vary as to their poisonous qualities, and that the

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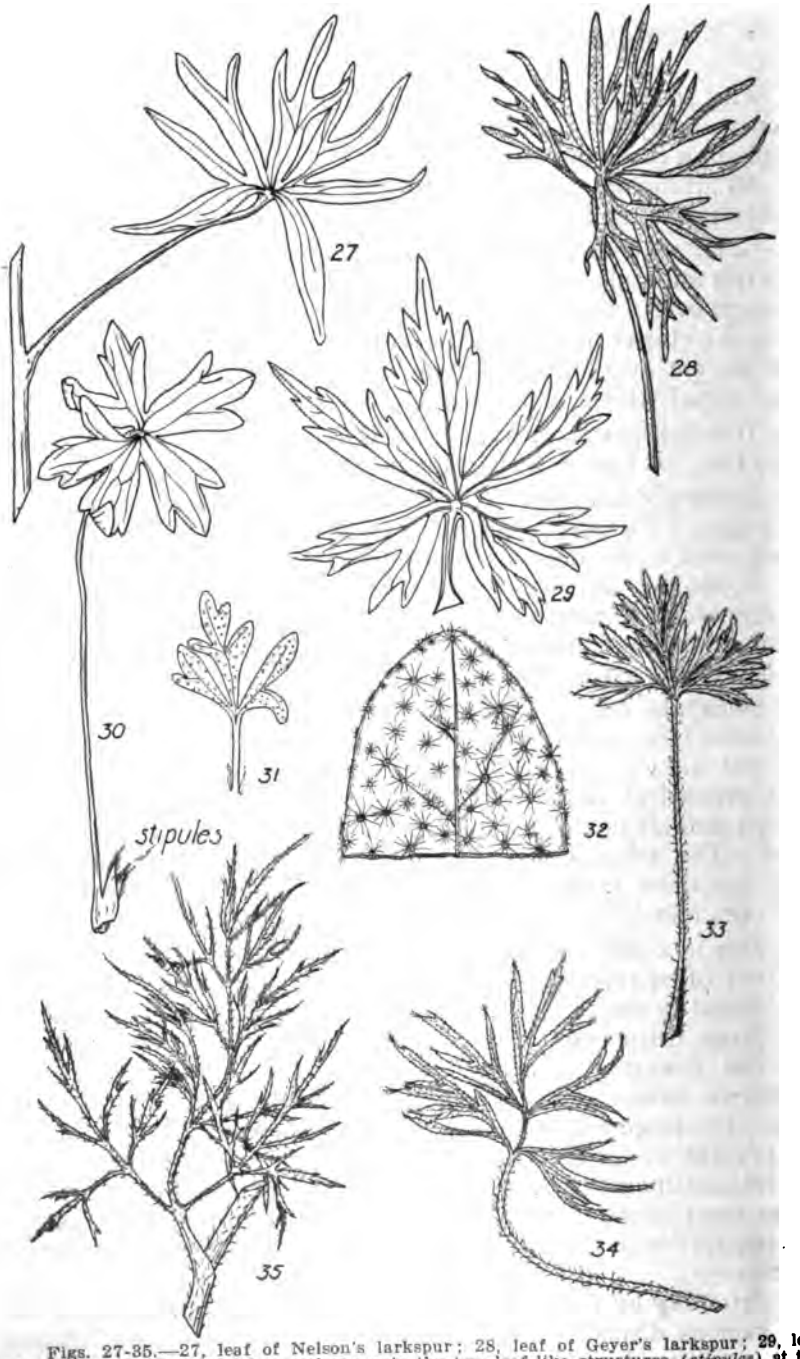

Figs. 27-35.—27, leaf of Nelson's larkspur; 28, leaf of Geyer's larkspur; 29, leaf of aconite; 30, leaf of wild geranium; note the two leaf-like structures (*stipules*) at the base of leaf stalk; 31, leaf of the false mallow; 32, portion of leaf of false mallow, enlarged, showing the star-shaped hairs of the surface; 33, leaf of wind flower; 34, leaf of anenome (*Pulsatilla*); 35, leaf of Virgin's Bower. Figs. 30 to 35, inclusive, are leaves of plants often mistaken for those of larkspur.

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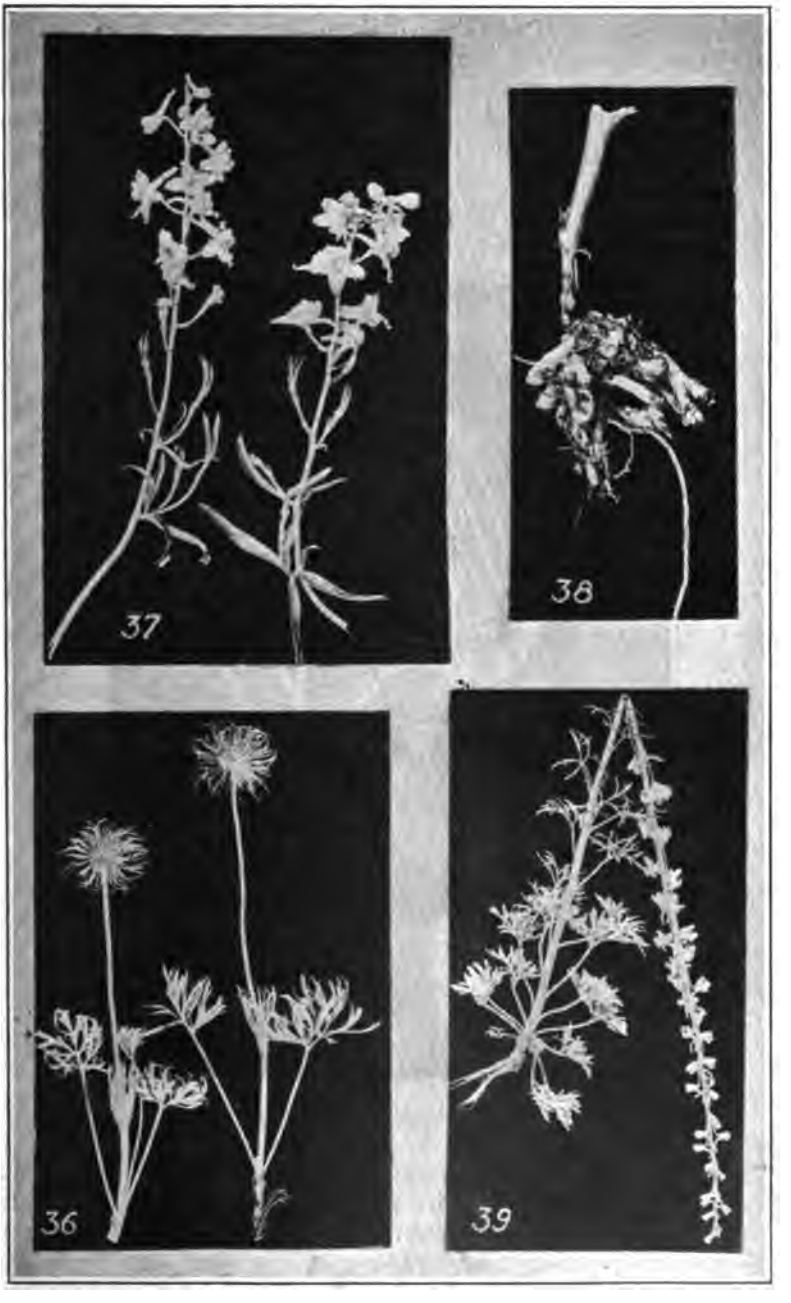

Figs. 36-39.—36, anenome (*Pulsatilla*), the leaves of which are frequently mistaken for those of larkspur; 37, leaves and flowers of Nelson's larkspur; 38, easily detachable cluster of thickened, tuberous roots of Nelson's larkspur; 39, Penhard's larkspur.

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poisonous qualities of any one of them is not to be depended upon at all times throughout the season. The white larkspur, which grows on the plains east of the mountains, has never been reported to the Experiment Station as having caused any trouble. Stavesacre which is derived from one species of larkspur has long been used in medicine. The eclectic physicians use it for its specific action on the reproductive organs but its principal use has been to destroy lice on the heads of children.

Fig. 40.—Geyer's larkspur (*Delphinium geyeri*).

Symptoms.—The symptoms manifested in affected animals are similar to those of aconite poisoning. Cattle are most often poisoned and the first thing noticed is stiffness, especially of the fore legs, and pronounced straddling of the hind legs in walking. The animal usually falls to the ground several times and the muscular movements become more and more irregular. There is drooling of saliva, with frequent swallowing. Perhaps the most char-

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acteristic symptom is the quivering of the muscles, especially on the sides and legs. In fatal cases the animal dies in convulsions. There is not sufficient difference in the symptoms of poisoning by the different species of larkspur to warrant special consideration of each.

It is a well known fact that animals are most often poisoned from eating larkspur when it is wet, after a rain or snow storm, or in the early morning after a heavy dew or frost.

Since larkspur and death camas are both found on the same range at a time when they are most poisonous, it may be difficult to tell in a given instance which is responsible. The symptoms are quite characteristic in each instance and a comparison of the symptoms given should enable the reader to decide with a considerable degree of certainty.

Animals when poisoned, and if not restrained, will start for the nearest water hole; the death of many animals near water holes has been deemed sufficient cause in many instances for suspecting that the water has been maliciously tampered with by an enemy.

Areas that are badly infested with larkspur should be abandoned until the danger period has passed, which period will vary, according to altitude, from the middle of June to the first of August. When limited areas are particularly infested with larkspur, the practicability of fencing and of digging the plants is to be considered.

Treatment.—When an animal goes down from larkspur poisoning it should be turned until the head is higher than the body, to relieve the breathing. Under no circumstances should attempt be made to drive the animal further. The benefit derived by bleeding the animal, as claimed by some stockmen is questionable. When there is excessive bloating the rumer (paunch) should be punctured on the left side with a sharp knife (withdrawing it immediately after the puncture is made), or what is far better, with a trocar and cannula. This latter instrument, which costs but a dollar or two, should be kept at the ranch and carried by the range rider during the larkspur season. Potassium permanganate, as a chemical antidote, is found to be very effective in larkspur poisoning (discussed in connection with remedies for death camas), but the inconvenience of carrying quart bottles of the solution ready for use, renders it of little practical value.

Dr. C. Dwight Marsh has reported very satisfactory results from use of the following formula, administered hypodermically:

Physostigmin salicylate	**1 grain**
Pilocarpin hydrochlorid	**2 grains**
Strychnine sulphate	**½ grain**

Most stockmen are familiar with the use of a hypodermic syringe, having used it in vaccinating cattle for blackleg. A 4-

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dram, all metal syringe will be the most convenient, and can be secured at any instrument house. The drugs can be secured at drug stores in tablet form, and after being dissolved in water, are ready for immediate use. The amount of each drug indicated in the formula is intended to be given at one dose for an animal weighing 500 or 600 pounds. One-half ounce of boiled water should be used to dissolve the tablets and two or three doses can be carried along with the syringe, for immediate use. Dr. Marsh expresses his confidence in the above treatment in the following words: "If they (stockmen) are willing to try this remedy, they can without doubt save the lives of most of the animals poisoned during drives or round-ups."

MONKSHOOD, ACONITE (*Aconitum*)

The common monkshood or aconite (*Aconitum columbianum*) (Figs. 39 and 41) in Colorado is a tall species, 3 to 6 feet high. The plant is more or less hairy and sticky. The large leaves are cut into a number of segments. The flowers have the characteristic "hood"; this feature has suggested the name "monkshood." The flowers vary from blue to white. The fruit (Fig. 26) is similar to that of larkspur. The species is prevalent in our mountains between the altitudes of 7,000 and 10,000 feet. Its preferred habitat is moist meadows and open woods. At 9,000 to 10,000 feet it is usually found growing among low shrubbery.

Poisoning by Aconite.—There is some confusion in differentiating aconite from its near relative larkspur. In one locality on the western slope the tall larkspur has for years been called aconite. Aconite is a very poisonous plant but because of its limited distribution, and its widely scattered habit of growth, it is not much eaten. Animals have been seen to reject the plant even after taking it in the mouth, because of its peculiar local effect. The general effect of aconite is much the same as larkspur. There is great muscular weakness, shallow, irregular and labored breathing, a small and weak pulse, bloating, belching, drooling frothy saliva, and often a peculiar clicking sound caused from the constant attempt at swallowing. The pupils of the eye may be either contracted or dilated, but as the end approaches, remain dilated.

Treatment.—This consists essentially in overcoming the depression of the heart. Inhalations of ammonia, camphor, sulphuric ether, and hypodermic injections of digatalin or atropine. The formula recommended for hypodermic use in case of larkspur poisoning is quite appropriate in this case.

WILD CHERRY (*Prunus*)

The three common species of cherry in Colorado are the chokecherry (*Prunus melanocarpa*), wild red cherry (*Prunus pennsylvanica*), and sand cherry (*Prunus besseyi*).

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Fig. 41.—Aconite (*Aconitum columbianum*)

Chokecherry (*Prunus melanocarpa*) (Fig. 42).—This is a tall shrub or small tree, sometimes attaining a height of 15 to 20 feet. The leaves are rounded or slightly heart-shaped at the base and pointed at the tip; the margin is marked by fine teeth. The flowers, of the true cherry type, are in long, unbranched clusters (see Fig. 42), and in this respect chokecherry is distinguished from the wild red cherry and sand cherry; the two latter have the flowers in short clusters in the leaf axils. The ripe fruit of the chokecherry is black and has an astringent taste.

Chokecherry is found on plains and foothills throughout Colorado. It is quite a characteristic gulch plant.

Wild Red Cherry (*Prunus pennsylvanica*) (Fig. 43).—This is a small tree, in our region, seldom reaching a height of over 30

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Fig. 42.—Chokecherry (*Prunus melanocarpa*)

Figs. 43-44.—43, wild red cherry (*Prunus pennsylvanica*); 44, Bessey's sand cherry (*Prunus besseyi*).

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feet, usually much smaller, and even in some instances almost shrub-like. The leaves are 3 to 4 inches long and ½ to 1 inch wide, rounded at the base and pointed at the tip; the margin is finely toothed. The flowers occur in the leaf axils, four or five in a group, all the flower-stalks arising approximately from the same region on the stem. The small, spherical fruit has a light red color.

In Colorado, wild red cherry occurs along streams and on hillsides. It seems to be found only in the eastern half of the State, on plains and in the foothills.

Sand Cherry (Prunus besseyi) (Fig. 44).—The sand cherry is a low, often prostrate shrub, frequently but a few feet high. The leaves are thick, elliptic and toothed along the margin. The fruit is quite large, reddish-yellow in color. The sand cherry belongs to the plains of eastern Colorado, growing in dry, sandy and stony localities.

Poisoning by Wild Cherry.—The partially wilted branches of wild cherry are poisonous for cattle. The poison is prussic or hydrocyanic acid. The eating of the plant at the particular time when conditions are right for poisoning is not common. The symptoms and treatment for poisoning by foods that develop prussic acid will be found in connection with the discussion of sorghums.

PEA FAMILY (*Legumes*)

Before taking up a discussion of lupine and the locos, it will be well to give some general characteristics of the family of plants to which they belong. All members of the pea family are popularly known as "legumes." To this group belong such well-known plants as peas, beans, alfalfa, vetch, clover, cow-pea, sweet clovers, peanut, wild liquorice, buck bean, lupine and locos. Probably no family of plants is of greater agricultural importance, except it is the grass family. In addition to the important forage and human food value of members of the pea family, they have an important relation to soil fertility. Bacterial nodules are formed on the roots, and through the action of these and other soil bacteria, the soil is enriched in nitrates. For this reason, legumes are regularly employed as rotation crops with cereals and root crops. The flower of all legumes is characteristic. The accompanying figures are intended to make its structure clear. An examination of the flower of the alfalfa, pea or loco will, with the aid of figures 49 and 50, help one to get the pea type of flower fixed in mind. There are five greenish structures (sepals), at the base of the flower. They partially enclose the colored parts (corolla) of the flower. There are four main parts to the corolla of the flower; a broad upper one

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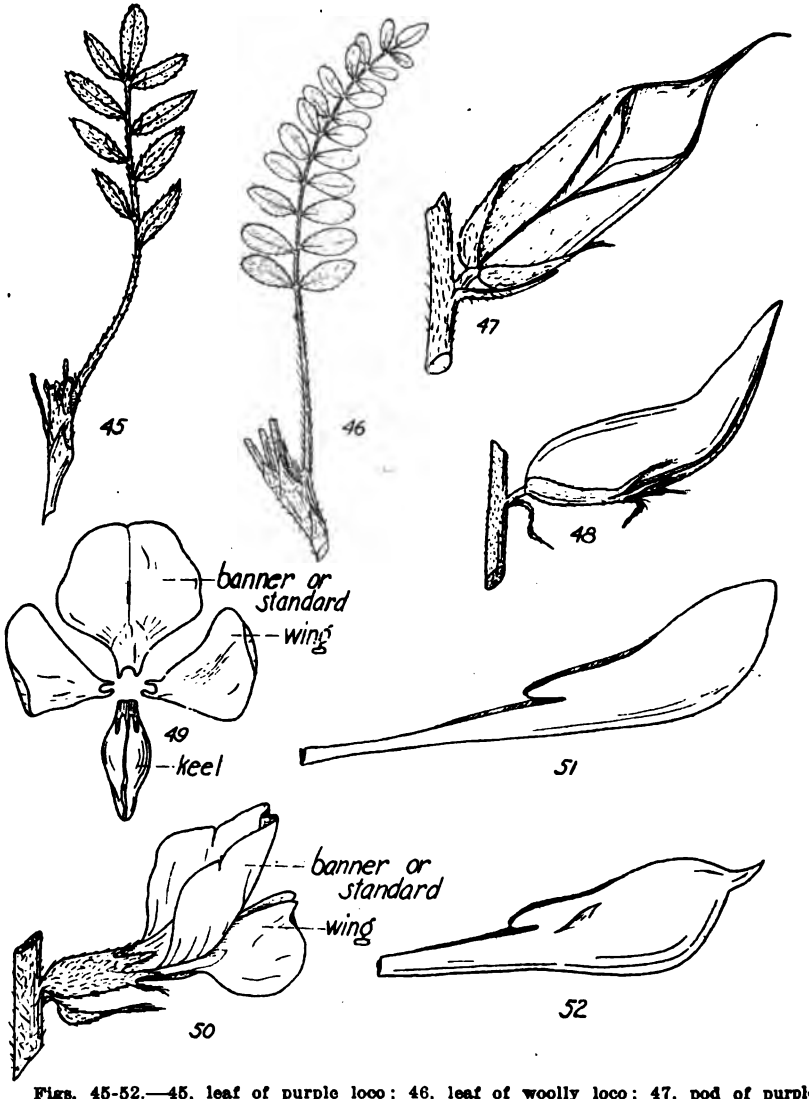
(*banner or standard*), two *wings*, one on each side, and a lower structure shaped like the keel of a boat, and called the *"keel."* The keel is really composed of two petals which are united along the middle line of the keel. It encloses the stamens, which produce the pollen, and also the ovary, which develops into the pod. The fruit of all peas is a pod or "legume." It consists of two halves which split apart (Fig. 47) at maturity along their edges. There may



Figs. 45-52.—45, leaf of purple loco; 46, leaf of woolly loco; 47, pod of purple loco; 48, pod of woolly loco; 49, diagram of pea flower, dissected; 50, side view of purple loco flower; 51, keel of woolly loco; note the blunt point; 52, keel of purple loco; note the sharp point.

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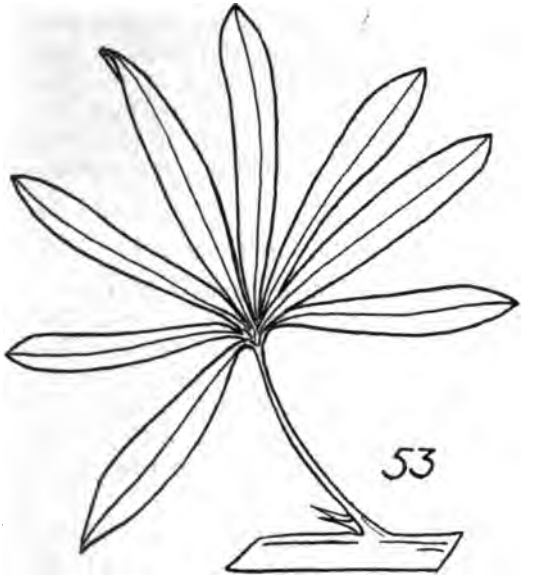

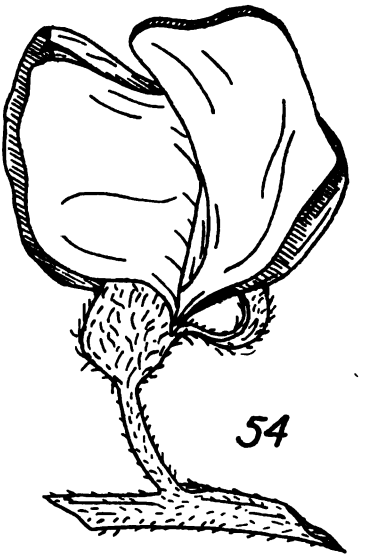

Figs. 53-54.—Spreading lupine (*Lupinus decumbens*). 53, single leaf; 54, flower.

Figs. 55-56.—Spreading lupine (*Lupinus decumbens*): 55, flowers and fruit; 56, single plant; it is about 2 feet tall.

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be one or more seeds in a pod. For example, in the twisted pod of alfalfa there may be but one seed, while in the bean or pea there are several seeds. The leaves of all members of the pea family are divided into a number of divisions; that is, they are compound. And, at the base of the leaf-stalk, where it joins the stem, are almost always two small leaf-like structures, the *stipules* (Fig. 46).

LUPINE, WILD BEAN, BLUE BEAN (*Lupinus*)

Lupines are herbaceous plants. They have leaves with the divisions all radiating from the end of the leaf-stalk (Fig. 53). The flowers (Fig. 54) are usually blue, and almost as broad as long. The pods are straight and usually much flattened. According to Rydberg's "Flora of Colorado," Bulletin 100, Colorado Agricultural Experiment Station, there are 24 different kinds of lupine in Colorado, 6 or 8 of which are quite common. The others are recorded from but one or a very few localities.

The most common, at least conspicuous, lupines are tall, highly branching forms. A number of them form clumps, 1 to 2 feet tall. Very frequently a small annual lupine (*Lupinus pusillus*) is sent in by stockmen, being regarded with apprehension by them. This lupine is usually 4 or 5 inches high, much branched, and covered with long, stiff hairs. Another very common species is the spreading lupine (*Lubinus decumbens*) (Figs. 55 and 56). Each plant forms a dense clump, 1 to 3 feet high. The leaflets are green above and silvery-hairy beneath. The flowers are in very dense clusters, and vary from blue to white. This species is abundant in rather deep soil at lower altitudes. It is also found throughout the foothills.

Poisoning by Lupines.—Because of their practical importance, stockmen should become sufficiently acquainted with these plants to be able to recognize them at a glance. The white loco weeds are sometimes improperly called lupines. Lupines remain green and offer a succulent forage after most other plants have become dry. They are eaten mostly in the late fall and constitute one of the chief forage plants. Lupine is cut for hay in Montana and is eaten greedily by all kinds of stock. The principal poison in lupine is lupinotoxin and it is confined mostly to the seeds and seed pods. The chronic condition of lupine poisoning is known as lupinosis. It is apparent that lupine hay, to be safe, must be cut either before the pods have formed or late in the season after the pods have matured and most of the seeds fallen out. While most poisoning occurs from feeding the hay containing the seeds, there are cases reported in which animals have been poisoned from grazing on lupines in the late summer and fall.

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Symptoms of Poisoning.—Chronic lupine poisoning is not common in this country, although a few cases have been noted. In acute cases there is cerebral congestion accompanied from the start by great mental excitement. Sheep are more often poisoned than horses or cattle. Sheep at first become frenzied, butt into things, fall over each other, show irregularity of movements, and finally have violent spasms, and in fatal cases die in convulsions. The symptoms somewhat resemble those of poisoning by strychnine.

Preventive and Remedial Measures.—Prevention consists in avoiding the ripe lupines both on the range and in the hay. Acute cases of lupine poisoning are not common in Colorado and no experiments have been made in treating the disease. Potassium permanganate would probably be effective as a chemical antidote if given early in the attack before too much poison is absorbed from the stomach. After absorption the physiological effects may be counteracted by morphine, chloral and other sedatives.

LOCO WEED

The name "loco weed" is applied to a great many different plants. The true locos and those which are commonly mistaken for locos all belong to the pea family. All are herbs. They have the typical pea flower: Five green sepals, a white, purple, or red corolla composed of a single large banner, two wings and a keel. The loco fruit is a pod ("legume"). The leaves are compound, that is, made up of a number of separate leaflets. There is always an odd number of leaflets (Fig. 45), which means that a leaflet, not a tendril, is at the tip of the leaf. In nearly all cases the leaflets are numerous, and come off on either side of the main axis of the leaf, seldom radiating from the end of the main axis, as in lupine.

The true locos and those resembling loco belong to two groups (genera) of the pea family. These groups are known by botanists as *Aragallus* and *Astragalus*. The common purple loco is an *Aragallus*, while the woolly loco is an *Astragalus*. Of course there are many different species of *Aragallus*, and also many of *Astragalus*. But the two large groups, with all their species, are distinguished from each other quite easily by an examination of the flower. If the two wings of an *Aragallus*, for example the purple loco (*Aragallus lambertii*) flower, are pulled aside so that one may see the tip of the keel, it will be seen that this is sharp-pointed (Fig. 52). On the other hand, the keel of the *Astragalus* flower, for example woolly loco, (*Astragalus mollissimus*) is blunt and rounded at the tip (Fig. 51). There are recorded nine different sorts of *Aragallus* in Rydberg's "Flora of Colorado," and in the same book 81 different species that might be referred to the genus *Astragalus*.

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As was intimated above, there are many different plants that are called loco weed. This name is most commonly applied, however to two species; these are the purple or stemless loco (*Aragallus lambertii*) and the woolly loco (*Astragalus mollissimus*). It is positively known that these two plants cause the loco disease. It is quite probable, however, that a few, at least, of the many allied forms, also possess poisonous properties. Many species, besides the purple loco and woolly loco, have been sent in to the Experiment Station, with the statement that they were the cause of locoing. Many of these species held in suspicion, resemble either the purple loco or the woolly loco. It is well for the stockman to thoroughly familiarize himself with the two known poisonous species, namely, the purple or stemless loco and the woolly loco.

Fig. 57.—Purple loco (*Aragallus lambertii*).

Purple or Stemless Loco (*Aragallus lambertii*) (Fig. 57).—The purple loco is perennial. It is apparently stemless. The numerous

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leaves and flowering stems arise from a hard, woody crown. The plant has a tufted appearance. Where the leaves join the crown, there are a number of papery scales (stipules). The plants are usually 8 to 14 inches high. Each leaf (Fig. 45) has a number of oblong to narrow leaflets, from ½ to 1¼ inches long. They are covered with silky hairs that lie closely against the leaf surface; often the leaves are smooth. The flowers (Fig. 50) are scattered along the end of a leafless stem. This stem may be silky hairy or smooth. The flowers are longer than broad. They are usually purple, but sometimes violet or white. The pod (Fig. 47) is oblong, hairy, rather leathery and measures about ½ to ¾ of an inch long.

Purple loco grows in dry, open soil. It is not found in low, moist land, or to any extent in shaded situations. It is found throughout Colorado, from the lowest altitudes up to about 9,000 feet. In the mountains it is most prevalent in the open parks, where it occurs in dry grassland. At the lower altitudes it is in bloom in early June. At 9,000 feet it comes into flower the latter part of June and the first of July.

There is a variety of the purple loco (*Aragallus lambertii sericeus*) which is stouter in appearance and has more silky, and broader leaflets than the regular form.

White-Flowered Loco (*Aragallus albiflorus*).—This grows in about the same habitats as the purple loco. It precedes the purple one, however, by a week or so. It also extends to higher altitudes (up to 11,000 feet). It is a more robust plant. It is covered with silvery hairs. There are silky white hairs on the calyx and with them, interspersed, a few black hairs. The flower is white, with a characteristic purple tip on the keel. The plant is held with suspicion.

Richardson's Loco (*Aragallus richardsonii*) (Fig. 58).—This is found only in the mountain valleys. It is readily distinguished from the preceding locos by the leaf; in it the leaflets are arranged in bundles of three or four on the stem. The whole plant is more or less hairy; the corolla is large and blue. Suspected of being poisonous.

Woolly Loco (*Astragalus mollissimus*).—This is a perennial (Fig. 59) with a short, stout stem from which arise numerous leaves, and stems bearing flowers. The entire plant is very densely hairy, the hairs being long, silky and somewhat matted together. There are numerous leaflets, which usually measure from one-half to five-eighths of an inch long. The violet-colored flowers are crowded; they are longer than broad. The mature pod is smooth, leathery, curved, and from one-half to three-fourths of an inch long.

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Fig. 58.—Richardson's loco (*Aragallus richardsonii*).

The woolly loco prefers dry soil. It is found only at lower altitudes in the eastern half of Colorado. It is a Great Plains plant (Fig. 61). It blooms in late May and early June.

Symptoms Resulting from Eating Locos.—The symptoms are so well known to stockmen that a lengthy discussion of them at this time would be superfluous. The condition may be summarized as a cerebral disturbance with impairment of the special senses and incoordination of muscular movements. Horses, cattle and sheep are affected. The claim is made in Montana that cattle are the least susceptible. The loco weed habit is acquired by imitation and encouraged by scarcity of forage grasses. Stock are not liable to eat poisonous plants when good food is available. If stock can be kept from acquiring the habit when food is scarce, there will be very few locoed animals. When first seen eating large quantities of loco weeds, and presumably acquiring the habit, an animal should be immediately removed from the herd. Young animals are more

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Fig. 59.—Woolly loco (*Astragalus mollissimus*).

apt to acquire the habit than older ones. The habit assumes the form an insatiable appetite for loco weeds, and as a result from eating these exclusively, the animal suffers from an unbalanced ration and from lack of nourishment.

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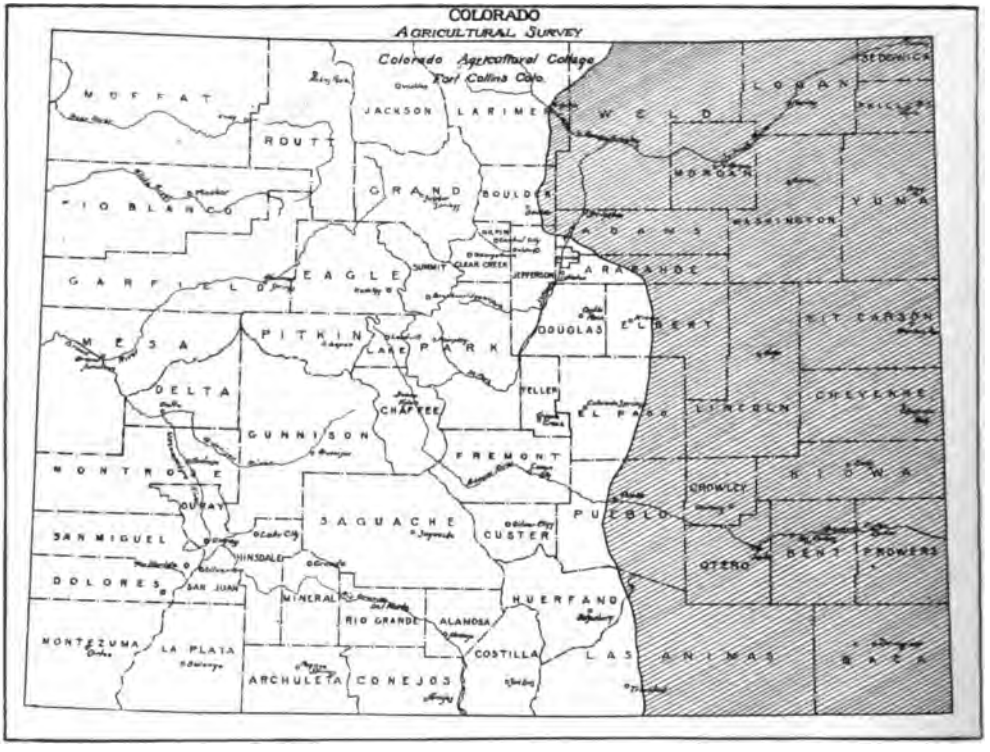

Fig. 61.—The shaded portion shows the geographical range of woolly loco in Colorado.

Poisonous Principle.—The nature of the poison in loco weeds has not been determined. It was thought at one time that barium found in the plants was responsible, since the symptoms in barium poisoning in some respects simulated those of locoism, but this was later disproven.

Preventive Measures and Treatment.—The most important measure is to remove the affected animals from loco-infested pastures. Many letters are received at the Experiment Station asking for a cure for locoed animals and in most instances the animals were known to still have access to the weeds. A "cure" in a case like this is impossible. The afflicted animal should first be taken from the infested area, and given a physic (raw linseed oil), and fed well on hay and grain of the best quality. Fowler's solution of arsenic mixed with the grain may be given as an alterative and tonic twice a day.

The dose for horses and cattle is one-half ounce, and for sheep one teaspoonful. This treatment should not be given continuously longer than two weeks. If the animal can be placed under the care

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of a competent veterinarian, strychnine and other remedial measures may be tried. If not too badly diseased, cattle and sheep, with good care and proper treatment, will recover sufficiently to fatten for the block. Horses will recover sufficiently, in most cases, to render a more or less valuable service. but with few exceptions they do not become normal and dependable.

BUCKBEAN (*Thermopsis*)

The common buckbean or yellow wild pea in the State is one with widely-spreading pods (*Thermopsis divaricarpa*). It is a tall perennial with large leaves divided into three leaflets that arise at and radiate from the end of the leaf-stalk. At the base of the leaf-stalk, there are two large, leaf-like structures. the stipules. The flowers are large, pea-like, and yellow. The pods are 3 to 4 inches long, 1-4 inch wide, and spread out from the stem. The plant blooms in the early spring, forming large, bright yellow patches. It grows in rather deep soil along streams, and in draws. It is distributed throughout the state from 5,000 to 11,000 feet altitude.

The buckbean is regarded with suspicion by some. No authentic cases of poisoning from it have come to our attention.

SNOW-ON-THE-MOUNTAIN (*Euphorbia marginata*)

This bright green, erect annual (Fig. 62), 2 to 4 feet high, is conspicuous, due to its white-margined upper leaves; hence the name "snow-on-the-mountain." The plant has a milky juice. It grows on the plains and lower foothills, and is most conspicuous in August.

Poisoning by Snow-on-the-mountain.—More than one hundred species of spurge grow in the United States and many of them are indigenous to Colorado. They have a milky juice that is acrid and corrodes the skin and mucous membranes whenever applied. The milky juice has been used imperically to remove warts and freckles. The snow-on-the-mountain is a very common plant, but is rarely if ever eaten by animals. The plant has not been sufficiently investigated to warrant any definite conclusion regarding its poisonous character. On some closely cropped ranges, this plant will be found as one of a few that has not been molested. Near Lamar, Colorado, where many sheep had died, presumably from eating poison weeds, this particular plant was found to have been denuded of foliage by grasshoppers but without any apparent diminution of their numbers. There was no evidence that sheep had eaten the plants.

SUMAC (*Rhus cismontana*)

The sumac (Fig. 63) of Colorado is a shrub 3 to 7 feet high. The compound leaves have numerous finely-toothed, smooth leaflets that are whitish beneath. The inflorescence is dense and spherical. The fruit is one-seeded and covered with reddish hairs. The

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Fig. 62.—Snow-on-the mountain (*Euphorbia marginata*). The upper leaves have white margins.

leaves turn bright red in the autumn. It is found throughout the State at lower elevations, usually forming thickets.

The red fruit of sumac is considered poisonous by some. No cases of poisoning, however, have been brought to our attention.

WESTERN POISON IVY, POISON OAK (*Rhus rydbergii*)

Western poison ivy (Fig. 64), or poison oak, is the only plant in the Rocky Mountain region that is poisonous to the touch. It is a low shrub, 1 to 2 feet high. Unlike the eastern poison ivy, it does not climb or creep. The leaflets come off in threes and when young are folded along the midrib, and quite frequently tinged with purple or dark red. The small yellowish-green flowers occur in clusters in the axils of the leaves. The fruit is globular, berrylike, shining-white, and often persistent on the plant during the winter. It usually grows in rather moist, shaded situations or among rocks. Poison oak or poison ivy should not be confused with scrub oak.

Some people are very susceptible to ivy poisoning. In the human it causes intense inflammation of the skin, with vesicles, edema, itching, and spreads rapidly. A few reports have come to this office to the effect that animals have been poisoned from eating poison ivy, but these reports have not been verified. From a veterinary standpoint, it has little signficance as a poisonous plant.

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Fig. 63.—Sumac (*Rhus cismontana*)

For poisoning by ivy, a popular and effective remedy consists in washing the inflamed skin with a solution made by adding powdered sugar of lead to alcohol, of 50% grade, until no more will easily dissolve.

SKUNK-BUSH (*Rhus trilobata*)

This is a much-branched shrub (Fig. 65), 2 to 5 feet high. The leaves are usually 3-lobed. The flowers are in dense clusters, small, yellowish, and make their appearance before the leaves. The fruit is spherical, red and covered with sticky hairs. The plant has an unpleasant odor, especially when bruised. It grows at lower elevations throughout Colorado, seldom going above 7,000 feet. It is not browsed by animals, because of its objectionable odor.

FALSE MALLOW (*Malvastrum coccineum*)

This is a low, silvery-hairy plant, 4 to 8 inches high. Leaf shape is shown in Fig. 31. The flowers have a characteristic brick-

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Figs. 64-65.—64, poison ivy (*Rhus rydbergii*); 65, skunk-bush (*Rhus trilobata*).

red color. The plant grows in dry soil throughout the State, from 4,000 to 9,000 feet elevation. Reports of poisoning by this plant have not been authenticated. Presumably, it is not poisonous.

COWBANE, WATER HEMLOCK (*Cicuta occidentalis*)

This very poisonous plant is a stout perennial, 3 to 7 feet tall. The stem is hollow, smooth, and green. The plant has a very characteristic bunch of thick spindle-shaped roots which contain a yellow, gummy secretion. These are further characterized by being divided into chambers, internally, by cross-partitions. These features are brought out in Fig. 66. Common garden parsnip (*Pastinaca sativa*) that has gone wild, and popularly known as "wild parsnip," is readily mistaken for the water hemlock. The wild parsnip, however, has a single thick, fleshy root (Fig. 67), and not a cluster of roots, as has the water hemlock. These two plants are also distinguished by their leaves (Figs. 68, 71 and 72). The leaves of water hemlock are doubly divided. the leaflets being finely toothed along the margin. The stem of cowbane (Fig. 70) is smooth, that of wild parsnip (Fig. 69) roughened. The small, white flowers are arranged in umbels as in common parsnip (Fig. 74); the fruit resembles that of parsley.

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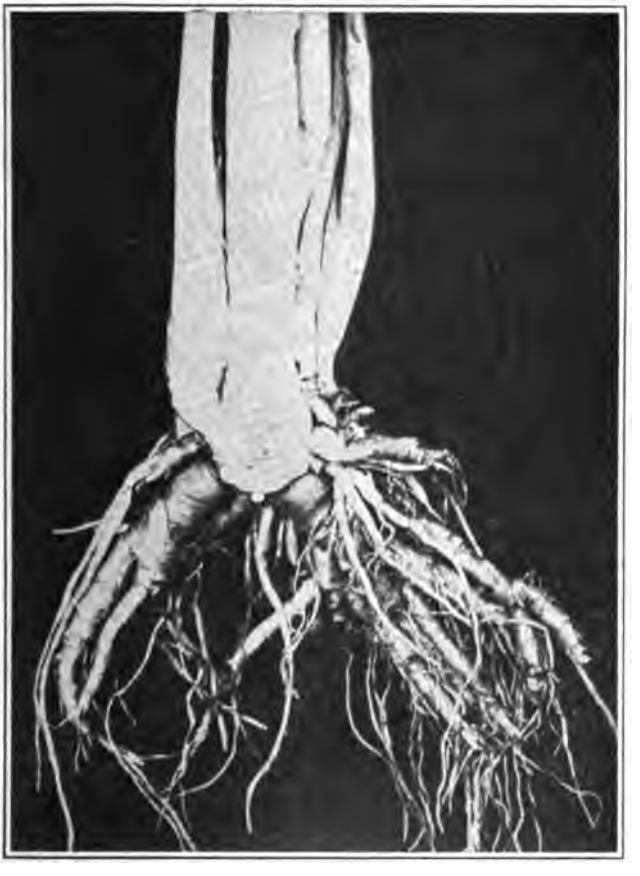

Fig. 66.—Roots of water hemlock (*Cicuta occidentalis*). Note that the spindle-shaped roots are clustered; also observe the cross-partitions.

Water hemlock is found throughout the Rocky Mountain section from 4,000 to 8,000 feet elevation. It grows in wet or swampy situations, on streams and ditch banks.

Water hemlock has been distinguished from ordinary garden parsnip in its wild state. It is also sometimes confused with the water parsnip (*Sium cicutaefolium*) (Fig. 73). This plant belongs to the same family (parsnip or carrot family) as water hemlock, and is found growing in wet places, but it does not have a cluster of fleshy roots as does the water hemlock; furthermore the leaves are not doubly compounded (Fig. 73). The water parsnip has been noted in but a few localities of the State. It is reported as poison-

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Figs. 67-73.—67, root of common wild parsnip; note that there is a single root; 68, leaf of water hemlock; 69, cross section of stem of common wild parsnip; 70, cross section of stem of water hemlock; 71, end leaflet of leaf of common wild parsnip; 72, lateral leaflet of common wild parsnip; 73, leaf of water parsnip sometimes mistaken for water hemlock.

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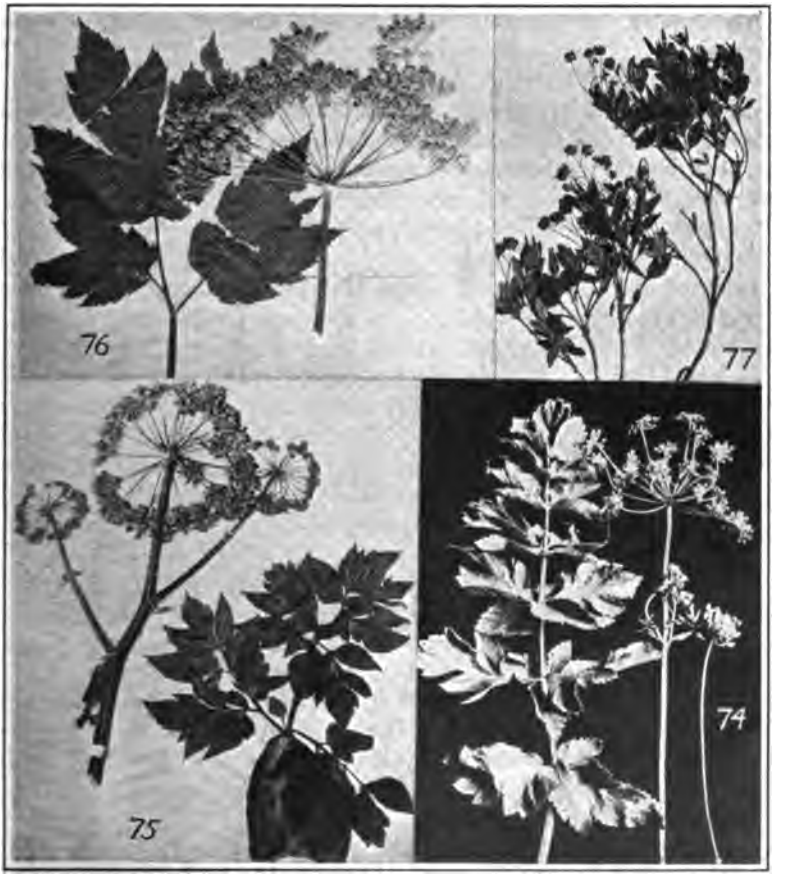
ous, but it is likely that it has been confused with the water hemlock.

Poisoning by Water Hemlock.—The American water hemlock is one of the most poisonous plants native to the United States. Every year cases are reported of people, more often children, poisoned from eating the roots of water hemlock, mistaking it for wild garden parsnip. Most of these cases are fatal. The root of a single plant has been known to kill a horse in little less than an hour. Poisoning usually results from eating the roots, but there are instances in which fatal poisoning followed from eating the tops of young plants, and there is strong suspicion that the dried plants in hay may at times be eaten in sufficient quantity to cause poisoning. The roots become accessible by plowing, or, as



Figs. 74-77.—74, common wild parsnip (*Pastinaca sativa*); 75, tall angelica (*Angelica ampla*); 76, cow parsnip (*Heracleum lanatum*); 77, swamp laurel (*Kalmia polifolia*).

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frequently happens, the earth is washed away from around the roots on ditch banks. The roots are eaten with more apparent relish than are the dried tops, by both cattle and horses.

Symptoms of Poisoning.—The symptoms are quite characteristic and should be easily differentiated by the layman from those of camas, loco, larkspur or lupine poisoning. The first pronounced symptom is akin to acute spasmodic colic without intermissions from pain. Frequent attempts at micturation and defectation are accompanied by spasmodic contractions of the muscles of the abdomen. The animal is in great agony, and, when prostrate, beats its head violently upon the ground. There is "frothing at the mouth" and in cases that last for several hours, blood may appear in the feces and urine. The spasms rapidly become more and more severe as the brain excitement increases, and the animal finally becomes unconscious and dies in the most violent convulsions.

Treatment.—In very acute cases animals may die in fifteen minutes; in such, treatment is out of the question. If potassium permanganate (as recommended in connection with death camas) can be administered early, it probably will be effective. Melted lard and raw linseed oil are indicated. To relieve the pain, morphine may be given in doses as follows: For sheep, 1½ grains; for cattle and horses, 3 to 5 grains. For horses or cattle, 2 drams of chloroform or 1 ounce of chloral hydrate may be given, highly diluted, by the mouth. If the permanganate has already been given, other drugs should not be given by the mouth.

Cow Parsnip (Heracleum lanatum) (Fig. 76).—This is a stout plant, 4 to 8 feet tall, with large compound leaves that are divided into three main lobes. The base of the leaf-stalk is very much broadened. The flowers are white and in broad umbels. The fruit resembles that of common garden parsnip. It grows in wet ground, especially along streams, throughout the State from 5,000 to 10,000 feet altitude.

The cow parsnip may sometimes be confused with the tall angelica (*Angelica ampla*) (Fig. 75). This is a plant from 5 to 8 feet tall, but is distinguished from the cow parsnip by its purplish stems, and leaves which are twice compound.

The cow parsnip is found in situations similar to those in which water hemlock grows. It can easily be distinguished from the water hemlock, however, by its much greater size, and coarser character. Because of its coarseness, it is not often eaten and is not presumed to be poisonous.

AMERICAN OR SWAMP LAUREL (*Kalmia polifolia*)

The forms of the American or swamp laurel (Fig. 77) growing in the Colorado mountains are dwarfed as compared with the

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eastern ones. With us it is a low, smooth shrub, 8 to 20 inches tall. The leaves are evergreen, shiny-green above, paler beneath, the margin often rolled in. The flowers are half an inch broad and lilac-purple in color. The plant grows in mountain bogs, seldom below 10,000 feet elevation.

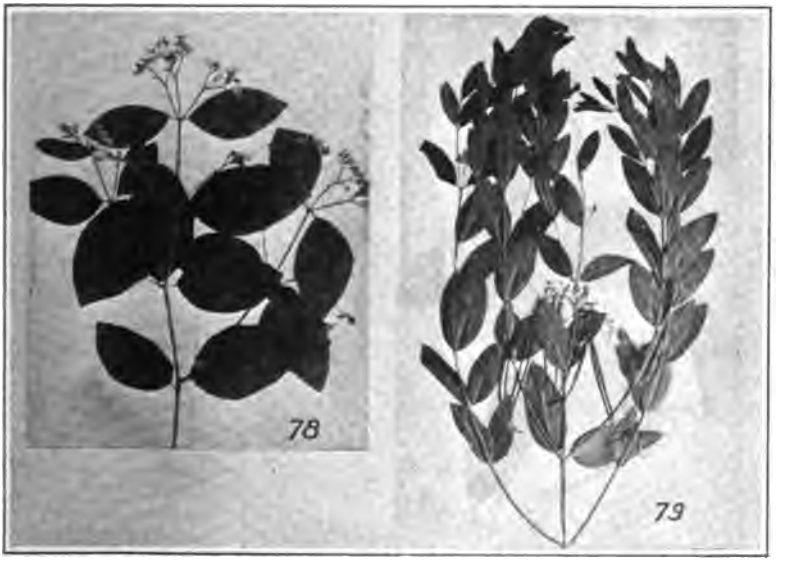
Poisoning by Swamp Laurel.—Colorado stockmen generally know very little of swamp laurel as a poisonous plant. This is probably accounted for from the fact that it grows only on the very high ranges, where relatively few animals graze. It is much dreaded in some sections, however.

SMALL DOGBANE (*Apocynum androsaemifolium*)

This plant (Fig. 78) has a milky juice. It grows from 1 to 3 feet tall, and has widely spreading branches. The opposite leaves are tipped with a very short abrupt point. The flowers are pink.

The plant grows in shaded situations throughout our range, from an altitude of 7,000 to 9,500 feet.

Indian Hemp (*Apocynum cannabinum*). Like the preceding, this plant (Fig. 79) has a milky juice. The stems are 3 to 6 feet tall, and branching. The leaves are opposite and tipped with a short abrupt point. The flowers are greenish-white. It grows at lower altitudes throughout Colorado.



Figs. 78-79.—78, small dogbane (*Apocynum androsaemifolium*); 79, Indian hemp (*Apocynum cannabinum*).

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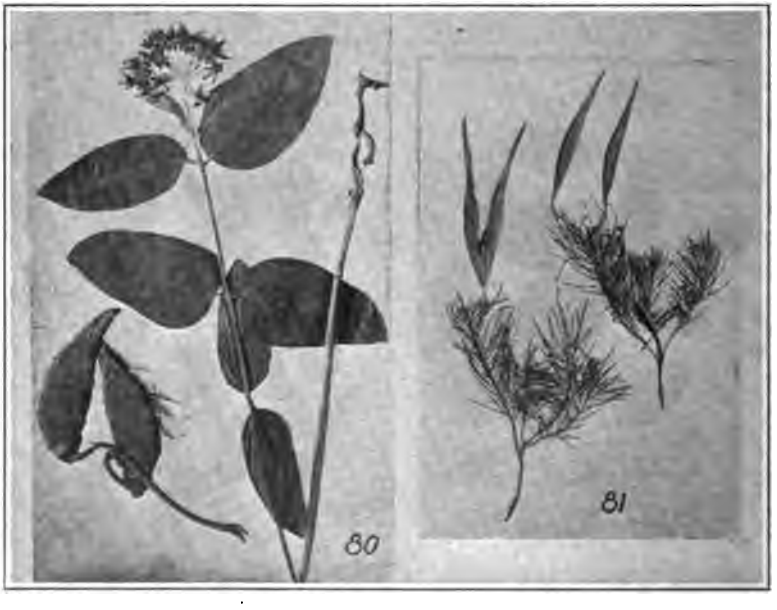
Poisoning by Dogbane and Indian Hemp.—Several representatives of the dogbane family contain active alkaloids which are used in medicine. Indian Hemp is perhaps the best known. It is used as an emetic, cathartic and diuretic. It contains the glucoside *apocynein* and a bitter extractive *apocynin*. Both dogbane and Indian hemp are looked upon with suspicion by stockmen, and they no doubt poison animals occasionally.

MILKWEED (*Asclepias*)

The milkweeds, as a group, are quite well-known. All of them are regarded with suspicion by stockmen, and in some cases at least, this suspicion is justified. All plants with a milky juice are not "milkweeds", that is, of the group known botanically as "*Asclepias.*" For example, prickly lettuce, sow thistle. and prickly poppy all have a milky juice, yet are not true milkweeds. The three above-mentioned have alternate leaves, while the true milkweeds have opposite leaves.

There are many species of true milkweeds within our borders. All are herbs, with opposite leaves (rarely alternate), or sometimes several at a joint on the stem. The leaves and stems are often somewhat woolly, sometimes smooth. The flowers are in umbels, pink, purplish, or white in color. and peculiar in shape. The fruit is a pod which splits open at maturity allowing numerous seeds to come out, each of which has a silky tuft of hairs at the end.



Figs. 80-81.—80, showy milkweed (*Asclepias speciosum*); 81, low milkweed (*Asclepias pumila*).

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The most common milkweed in our section is the showy milkweed (*Asclepias speciosa*) (Fig. 80). It is perennial, 2 to 5 feet high, with large, opposite leaves, and purplish flowers in spherical, terminal clusters. It grows in good, rather moist soil on plains and in foothills throughout the State.

The low milkweed (*Asclepias pumila*) (Fig. 81) is 2 to 15 inches tall, and grows from a woody root. The leaves are very narrow and crowded on the stem. The pods are long, slender and

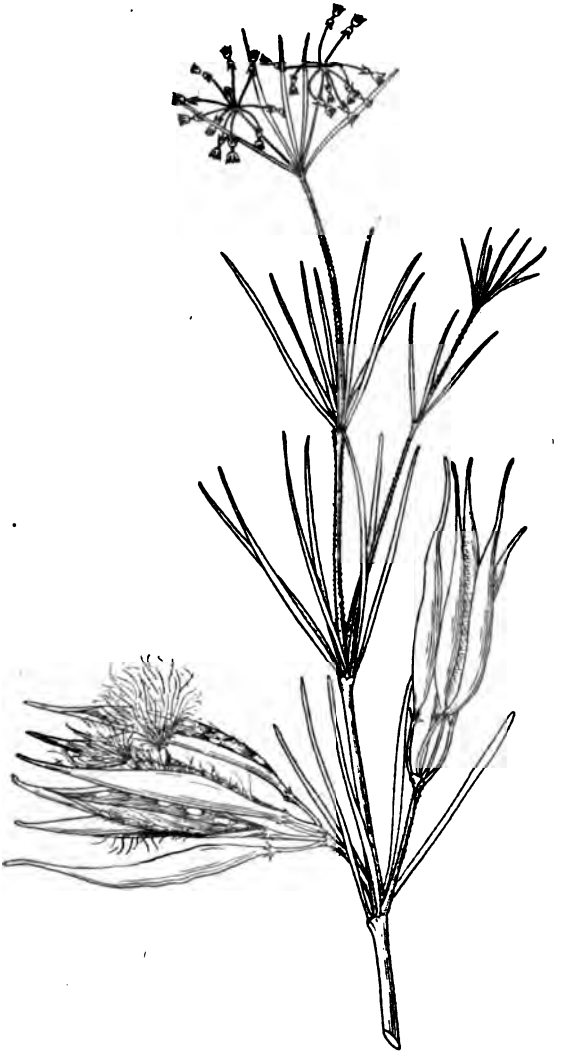

Fig 82.—Whorled milkweed (*Asclepias verticillata*).

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much smaller than those in the preceding species. It prefers dry, sandy soil. It is most common at low altitudes.

The whorled milkweed (*Asclepias verticillata*) (Fig. 82) is a leafy plant, 1 to 2½ feet high. The long, narrow leaves are several at a joint of the stem. It grows on dry plains.

There are several so-called green milkweeds in Colorado, the chief one being the green-flowered green milkweed (*Acerates viridiflora*). It is a plains plant.

Poisoning by Mildweeds.—Many of these plants have an acrid juice. The showy milkweed is said to be poisonous. It contains *asclepion*. Another species (*A. verticillata*) grows extensively along river bottoms and native meadows of Colorado, and is suspected of being poisonous. At Olathe several cattle that had eaten hay containing considerable quantities of this weed died with symptoms of poisoning. A sack of the plants was sent to the Experiment Station for examination. Rabbits refused to eat it and watery and alcoholic extracts were tried, but the chances are that the animals in this instance died from some other cause. While many of the milkweeds are poisonous they are for the most part rejected by animals.

BLACK NIGHTSHADE, STUBBLE-BERRY (*Solanum nigrum*)

An annual low, spreading plant (Fig. 83) with oval leaves. The white flowers are in small drooping groups along the side of the stem. They are of the potato type: 5-parted calyx, 5-parted corolla, 5 stamens. The berries are black, smooth and spherical. The plant is introduced from Europe and assumes weed habits with us. It occurs at low altitudes in the State, it is not abundant, however.

THREE-FLOWERED NIGHTSHADE, WILD TOMATO (*Solanum triflorum*)

A low, spreading annual (Fig. 84) with deeply cut leaves. The flowers are usually arranged in groups of three, on nodding stalks, hence the common name "three-flowered nightshade." The fruit is greenish, and about half an inch in diameter. The plant grows throughout the State from low altitudes up to 10,000 feet.

Poisoning by Nightshades (Solanums).—The nightshade family is a large one and contains important medicinal plants and several important food plants. Many plants of the group have poisonous properties. Neither the black nor three-flowered nightshade are known to poison stock extensively. Bittersweet, sandbur, horse nettle, bull nettle and the common potato all contain poisonous properties. A large number of plants of this group contain the alkaloid *solanin*, and nightshade also has a bitter principle *dulcamarin* and two more alkaloids *solanidin* and *solanein*.

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Fig. 83.—Black nightshade (*Solanum nigrum*).

Fig. 84.—Three-flowered nightshade (*solanum triflorum*).

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The tops and sprouts of the common potato are poisonous when green. The tubers are poisonous when they have turned green from exposure to the sun. Hogs have been poisoned by eating raw potatoes that were wilted and beginning to rot; cases are reported every fall in the potato district in which horses and cattle have been poisoned from eating potatoes left in the fields after harvest. In one instance an entire herd of hogs developed paralytic symptoms after feeding for some time upon a ration consisting almost entirely of raw potatoes that were more or less withered and sprouting. The black and three-flowered nightshades are not a tempting food for animals, which fact no doubt accounts for their being rated of so little consequence as poisonous plants.

SAND BUR (BUFFALO BUR) (*Solanum rostratum*)

A low annual plant, (Fig. 85) yellowish-green in color. The stems, leaf-stalks, flower stalks, and main veins of leaves are armed with stiff yellowish prickles. The deeply-lobed leaves are covered with hairs arranged in small star-shaped groups. The flowers are about 1 inch in diameter and yellow in color. The mature fruit is very prickly. Buffalo bur is a plant of sandy plains.

Fig. 85.—Sand bur, buffalo bur (*Solanum rostratum*).

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Sand bur is not known to possess poisonous properties. The prickles on the burs sometimes cause serious mechanical injury.

BLACK HENBANE (*Hyoscyamus niger*)

This is a coarse biennial (Fig. 86) plant 1 to 2 feet high. The leaves are wavy along the margin and clasp the stem. The flowers are large, dull yellow in color, with purple veins, and arranged along one side of the stem in a characteristic fashion. When the fruit is mature, it opens at the top by a lid (Fig. 87). The plant has been found in a few localities in western Colorado. It is common in eastern states.

Figs. 86-87.—**Black henbane (*Hyoscyamus niger*). 86, leaves, pods, and fruit; 87, single pod, showing how it opens at the top by a lid.**

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Poisoning by Henbane.—Dr. Chestnut says of black henbane: "One or two cases are recorded in foreign literature in which stock have been poisoned by eating the plant of their own accord, but there is very little danger from it, on account of its ill odor and harsh texture." It is from this plant that hyoscyamin is obtained for medicinal use. It is an anodyne, hypnotic and is poisonous.

JIMSON WEED, JAMESTOWN WEED (*Datura stramonium*)

A rather stout plant (Fig. 88) 1 to 4 feet high, with green stems, and leaves 4 to 8 inches long and angular toothed. The flower is showy, white and about 3 inches long. The fruit is an oval capsule, beset with long, stiff prickles. The plant has been found in waste places at a number of low altitude points in eastern Colorado.

Poisoning by Jimson Weed.—The poisonous alkaloids *atropine* and *hyoscyamin,* the active constituents of belladonna, are also found in the jimson weed. Hyoscyamin is the poison found in

Fig. 88.—Jimson weed (*Datura stramonium*).

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henbane and the symptoms caused by it are the same as from atropine. There are a few instances recorded in which cattle have been poisoned by eating the leaves of young plants; with few exceptions, however. Jimson weeds are rejected by animals.

THORN-APPLE, PURPLE STRAMONIUM (*Datura tatula*)

This is very similar to the preceding. It is distinguished from it by its purple flowers and purple stem. It is rare in this State. It is of little economic importance.

THORN-APPLE (*Datura meteloides*)

This plant often grows to be 3 or 4 feet high. The leaves are large, and wavy about the margin; the flowers are white, sweet-scented. 6 to 8 inches long, and the large, nodding pods are armed with short prickles. It is found along streams in southern Colorado, at low altitudes. It is suspected of being poisonous to animals.

WOODY ASTER (*Xylorhiza parryi*)

Although this plant (Fig. 89) has not been reported from Colorado, it may be looked for in the northern part of the State. It has been identified in Wyoming as the cause of the death of sheep. Herewith follows a description of the plant as taken from Bulletin 97, Wyoming Agricultural Experiment Station:

"This plant has a strong woody root more or less branched just at the surface of the ground. From these woody crowns tufts of short branches spring. These bear green, narrow leaves, 1 or 2 inches long, the whole tuft becoming at length several inches high, and finally producing in June. a considerable number of large, white, daisy-like flowers with a yellow center. If the leaves be

Fig. 89.—Woody aster (*Xylorhiza parryi*).

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examined, it will be found that they usually bear a considerable number of yellowish or brownish spots caused by a fungus."

The plant begins to leaf out about May 1, and to blossom about June 1. It grows upon gumbo clays such as are frequently found about lakes and ponds.

Poisoning by Woody Aster.—This plant is looked upon as the most disastrous plant for sheep in Wyoming. In Bulletin No. 88 of the Wyoming Experiment Station, the statement is made that stockmen estimate their losses a 14.6% and: "In terms of the last assessment valuation of sheep in Wyoming, this means an annual loss of more than $3,000,000. Sheepmen who have followed the business for the past ten years estimate that of the total losses noted, 60-70% have been caused by poisonous plants, and the remainder by coyotes." This bulletin summarized the investigation of woody aster partly as follows:

"1. The woody aster has been proven to be poisonous to sheep.

"2. The woody aster grows only on alkalied, gumbo-clay soils, and but for the one recorded season, is always heavily infested with the fungus, *Puccinia xylorrhizae*. The presence of the fungus may add to the poisonous character of the plant.

"3. Ninety to one hundred percent of the animals affected die.

"4. Aster poisoning is characterized by lassitude, difficult respiration, muscular weakness, bloat, and final prostration.

"5. Duration of illness: From a few hours to several days.

"6 Treatment: Purely symptomatic and none uniformly successful.

"7. Prevention: Avoid aster patches."

SNEEZEWEED

The name "sneezeweed" is applied to several species, the principal ones being *Helenium autumnale* and *Dugaldia hooperii*.

Helenium autumnale (Fig. 90) is a perennial, erect herb 1 to 3½ feet tall. The leaves are lance-shaped, slightly toothed along the margin; they clasp the stem, their lower edges being continuous with two wings that run down the stem. There are numerous yellow flowers of the sunflower type. The plant grows in wet ground and has been reported from a few localities in the State.

Dugaldia hooperii is a stout plant 1 to 3 feet tall, woolly-hairy, especially above. The stem is leafy, the leaves spatula-shaped, and 3 to 4 inches long. The flowers are of the sunflower type, and yellow in color. The plant is found in the mountains from 7,000 to 12,000 feet throughout the State.

Poisoning by Sneezeweed.—Sneezeweed contains a narcotic poison, and cattle, horses and sheep are no doubt occasionally

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poisoned by it. Dr. Chestnut says: "The fine-leaved sneezeweed has been reported from several of the Gulf States, where it is a troublesome weed, fatal to horses and mules. It is not known to what extent cattle may feed upon it with impunity, but the bitter principle in milk and meat sometimes met with in the Southern States is quite generally supposed to be due to these plants."

In the mountainous districts of Colorado, bitter milk and meat are not uncommon, and it can no doubt be safely attributed in many instances to the eating of this plant. Severe poisoning may result from eating large quantities of the plant.

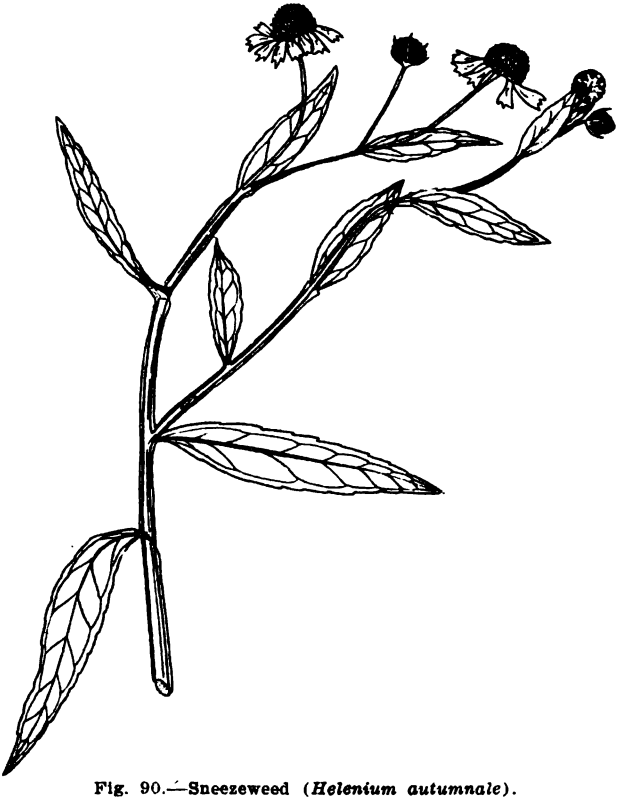

Fig. 90.—Sneezeweed (*Helenium autumnale*).

SAGE (*Artemisia*)

There are many different kinds of sages growing in the State. Rydberg's "Flora of Colorado" gives 39. A number of these are rare. The "sage brush" (*Artemisia tridentata*) of Colorado is a shrub 2 to 12 feet high with silvery leaves that have three characteristic teeth or lobes at the tip. The common low silvery herbaceous

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sage throughout the State from low to high altitudes is *Artemisia frigida*. The foliage of this is very finely divided.

Poisoning by Sage.—Western stockmen testify to the poisonous qualities of sage, and animals that have become affected by it are spoken of as "saged." Horses are mostly affected and the most pronounced symptom is a growing paralysis of the hind quarters. Some stockmen, with many years experience, avow that eating sage is fully as disastrous to their herds as are the loco weeds. The evidence of so many experienced stockmen is not to be wholly discredited and this subject is worthy of further investigation.

COCKLEBUR (*Xanthium echinatum*)

Cocklebur is an annual plant with thick stout stems that branch widely. The stem is often marked with dotted brown spots. The leaves may be oval in outline, or heart-shaped at the base. and usually have three main ribs. Stamens and pistils are in different flowers on the same plant. Cocklebur is best recognized by the spiny fruit. The "burs" are densely covered with long prickles. At the tip of the "bur" are usually two stout hooked prickles.

The plant is weedy in nature and may be found throughout the State at low altitudes.

Poisoning by Cocklebur.—Dr. Pammel in his "Manual of Poisonous Plants" makes the following statement: "The injury from this plant probably comes largely from its mechanical action. Stock will probably not eat very much of it, but on account of the hooked awns of the involucre the animal may have a considerable difficulty in removing them. The hairs of the plant cause itching. The plant contains the poisonous glucoside *xanthostrumarin* which resembles *datiscin*." According to Chestnut, the young seedlings of three species of cocklebur are poisonous for hogs. Dr. Biting thinks the injurious properties are largely mechanical.

COLORADO RUBBER PLANT (*Hymenoxys floribunda*)

This is an herb (Fig. 91) with an aromatic odor. Numerous stems arise from a woody base to a height of about 1 foot. The stems at the base are covered with woolly hairs. Each main stem is branched near the tip, each smaller branch being terminated by a yellow flower. The leaves are divided into several very slender divisions. The plant is found in dry soil at an altitude from 4,000 to 10,000 feet.

Poisoning by Rubber Plant.—Reports of serious losses in sheep from eating the rubber plant have come from Durango, Saguache and Middle Park. The plant is not known to contain any poison; the injurious effects are probably mechanical. It is thought that death results from the formation of indigestible masses that obstruct the digestive tract. On the ranges west of Saguache this is considered a most dangerous plant for sheep and they are systematically herded away from rubber weed patches.

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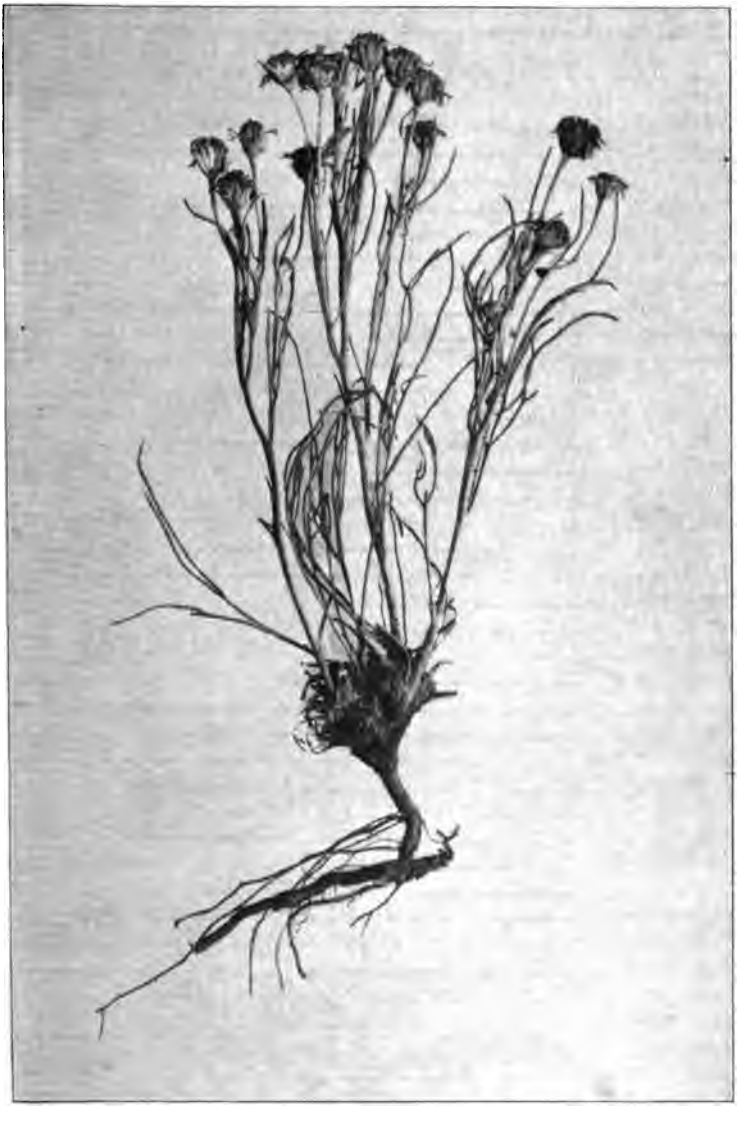

Fig. 91.—Rubber plant (*Hymenoxys floribunda*).

ACKNOWLEDGMENTS

All the drawings in this bulletin, with the exception of Fig. 59. were made by Mr. N. Lee Foster, to whom the writers owe acknowledgment. We express our thanks to the Wyoming Experiment Station for the use of the plate from which Figure 89 is made.

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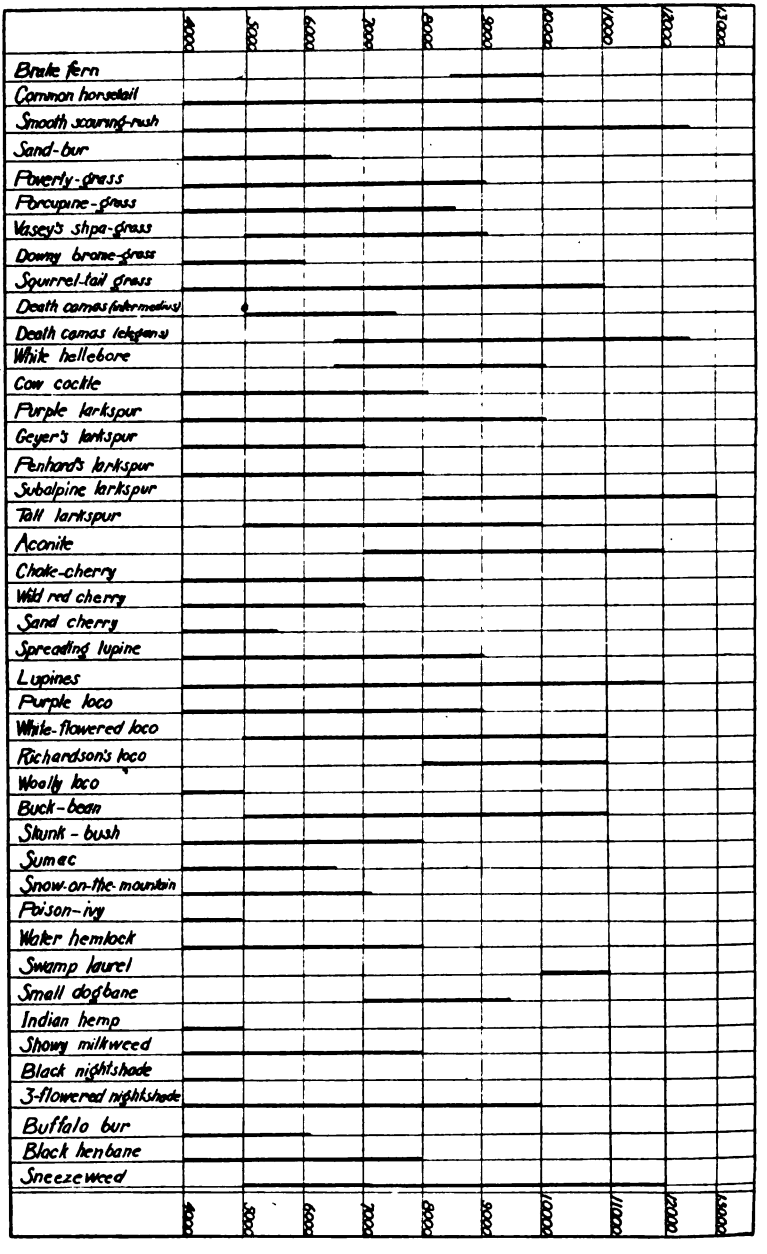

Fig. 92.—Altitudinal distribution of important plants injurious to livestock.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

FUNGOUS DISEASES OF COLORADO CROP PLANTS

By

WILFRED W. ROBBINS and OTTO A. REINKING

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FUNGOUS DISEASES OF COLORADO CROP PLANTS

By WILFRED W. ROBBINS and OTTO A. REINKING

INTRODUCTION.

Colorado crops, of orchard, garden and field, are not troubled with as many fungous diseases as are those of the states to the east and west which have a moister climate. Colorado's comparative freedom from fungous troubles causes frequent comment from those who are familiar with conditions as they exist in the east. Such destructive diseases as bitter rot of apple, brown rot of stone fruits, peach leaf curl and late blight of potato do no injury to crops in Colorado.

The direction of migration of economic plant diseases follows rather closely the direction of migration of man himself. Man is the chief agent in the spread of disease from one locality to another far distant. Prior to 1888, one finds little recorded mention of plant diseases within Colorado's borders. And we have reason to believe that up to that year and even up to several years later, fungous diseases of cultivated plants in Colorado were largely unknown or not serious enough to attract much attention. Today many diseases have permanently invaded the state. This has been due to more intensive cultivation in the state, to an introduction of a greater variety of host crops, and (until a few years ago) to a lack of proper inspection laws.

Crandall writes in 1891: "In all localities east of the mountains there is yet entire freedom from fungous diseases, with the exception of the occasional appearance of plum pockets on native wild varieties. The bacterial disease, variously known as 'pear blight,' 'apple tree blight,' 'twig blight,' is prevalent, and in some sections has done great damage. In the western districts diseases and insect troubles are at present unknown, but it can hardly be hoped that the immunity now enjoyed will continue. Growers in that district should prepare themselves to profit by the experience gained elsewhere and meet the first attacks with determined efforts at extermination." This was in 1891. Some years later, in 1898, Crandall (Crandall, C. S.. 11th Annual Report Colo. Exp. Sta. for 1898) reports as follows: "Colorado orchards have in past years been free from fungous diseases, but the diseases which have given the eastern growers trouble are gradually coming in and

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there is a rapidly growing interest in them among the fruit growers."

The first disease to attract attention in Colorado was the twig blight of pear and apple. In 1888, Cassidy (Cassidy, James, "Apple Twig Blight," 1st Annual Report Colo. Agr. Exp. Station, pp. 64-70, 1888) reported this disease near Fort Collins, as appearing in the latter part of June and continuing until late in August. He considered this trouble on the apple to be identical with fire blight of pear and a similar trouble on Lombardy and other species of cottonwood. Blight of pear and apple has become increasingly serious throughout Colorado. In 1891, Crandall (Crandall, Chas., "A Preliminary Report on the Fruit Interests of the State." Bull. No. 17, Colo. Agri. Exp. Sta., 1891) comments that the "bacterial disease variously known as 'pear blight,' 'apple tree blight' and 'twig blight' is prevalent and in some sections has done great damage." In 1898, (Crandall, C. S., "Blight and Other Plant Diseases," Bull. 41, Colo. Exp. Station, 1898) Crandall indicates that the disease had brought numerous inquiries to him. We judge from this that it had become more widespread. Paddock (Paddock, W., 22nd Annual Report State Board of Agriculture, 1900) reports a body blight of apple and pear known in some localities as "crater blight." This is now considered to be due to the organism causing fire blight. In 1903, Paddock (Paddock, W., Bull. 84, Colo. Exp. Sta., 1903) showed that apricot blight was the same as pear blight. It seems well established now that the bacterial organism, *Bacillus amylovorus,* may cause a blight on pear, apple, quince, apricot and plum, known by such common names as pear blight, fire blight, twig blight, apple blight, blossom blight and body blight. From the foregoing brief historical sketch of pear blight in Colorado, we see that since its appearance in 1888, it has become more widely spread in the state and its attacks have increased in severity.

The history of potato diseases in Colorado is as instructive as that of pear blight. The first mention of potato troubles in Colorado is found in a publication by Paddock and Rolfs, (Paddock, W., and Rolfs, F. M., "Potato Failures," Bull. 64, Press Bull. No. 8, Colo. Exp. Sta., 1901) in 1901, in which they call attention to potato failures in various sections, due probably to *Rhizoctonia.* They indicate that this disease has "undoubtedly been present in our potato fields for a long time." They say that little blight (*Fusarium*) is in evidence. In 1902, Rolfs (Rolfs, F. M., "Potato Failures," Bull. 70, Colo. Exp. Sta., 1902) published a preliminary report on *Rhizoctonia,* describing the occurrence and effects of the disease on the potato, the nature of the fungus, and giving the results of inoculation and preventive experiments. This is our first valuable

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account of *Rhizoctonia* in Colorado. In 1904 (Rolfs, F. M., "Potato Failures," Bull. 91, Colo. Exp. Sta., 1904) Rolfs published further notes on *Rhizoctonia*, in which he gives additional information relative to the life history of the fungus, its injuries, spread, and remedial measures.

The first mention of potato blight (*Fusarium*) is found in a press bulletin by Paddock in 1906 (Paddock, W., "Potato Problems," Press Bulletin No. 26, 1906). Within the last few years, and particularly during 1911 and 1912, *Fusarium* has seriously crippled the potato industry in many parts of the state. It is doubtful, however, if the organism, *Fusarium oxysporum*, is responsible for all the potato troubles in districts suffering.

Other potato diseases such as early blight, internal brown spot, and potato scab have not developed in severity as have *Fusarium* and *Rhizoctonia*. Both of the latter diseases have made remarkably rapid progress in the state. This is largely due to the general practice of growing potatoes continuously year after year on the same soil. Colorado potato failures, although lamentable, have been a blessing in disguise. They have brought forcibly to our attention the necessity of a proper system of crop rotation and the more general adoption of diversified farming. Crop rotation is a highly reliable practice in the control of a great majority of diseases of field and garden crops.

It is well that we keep on the watch for the first appearance of fungous diseases in the state. In many instances, the immediate suppression of a disease that has just been introduced may mean the saving of thousands of dollars to an entire community. Fungous diseases fluctuate in prevalence from year to year, largely depending upon climatic and weather conditions. If a disease is very bad one year, the chances are that there will be an abundance of infection material near at hand the following season. However, it sometimes happens that a serious outbreak is followed by a year of comparative freedom from disease. On the other hand, a serious outbreak may follow a year during which little disease was present.

The Department of Botany of the Experiment Station will be ready at all times to identify promptly plant diseases that are sent in, and suggest remedies.

DISCUSSION OF CHIEF FUNGOUS DISEASES

ALFALFA.

BACTERIAL BLIGHT.—Diseased plants are stunted and lighter green in color than normal. Stems chiefly infected. Infected portions at first are water-soaked in appearance, and olive green in

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color. Small drops of a sticky amber liquid, which soon dries with a glistening finish, later turning brown and then black, may collect over diseased portion. In advanced stages, the stems shrivel, become brittle, turn black, and die. Diseased leaves show a water-soaked appearance and an orange yellow coloration along the leaf-stalk and midrib. Later, they dry up and become brittle. On one-year-old plants, the whole crown may become infected, turn black, and die. The disease is caused by a bacterium which attacks the first crop only and then lives over until next season in the soil and on old stems. In years when late frosts are prevalent, the disease is most severe.

Control—As soon as danger from late frosts is past, clip the frosted alfalfa. By so doing, the stems split by freezing and hence subject to attack by the causal bacterial organism will be removed and new sprouts given a chance to grow.

Plate I. Alfalfa leaf spot.

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DOWNY MILDEW.—This disease has become increasingly abundant in Colorado, since it was first noticed in 1906. However, it has not become serious, except in a few localities. The leaves at tips of branches are usually attacked, turning yellow-green or yellow-gray to purple. A fuzzy growth develops on the under side of the leaf, which is grayish at first, and later violet.

Control.—Do not irrigate excessively. Do not crowd plants, as it makes them more liable to attack.

LEAF SPOT.—The disease first attacks lower leaves. Diseased spots are local, brown to black or yellow, circular, and with irregular edges (Plate I). Affected leaves usually turn yellow and drop prematurely. The trouble occurs in both old and new fields, and under very different soil conditions.

Control.—Since alfalfa leaf spot is widespread and easily disseminated, control-measures are not entirely satisfactory. If disease is serious, mowing of infested field when leaves begin to turn yellow will hold the disease in check.

APPLE.

FIRE BLIGHT.—See Pear, page 34.

APPLE ROT—BLACK MOLD.—The fruit is attacked usually at the blossom end. Spots are formed which at first are small, dark purple-brown, and slightly sunken (Plate II). Affected tissue is

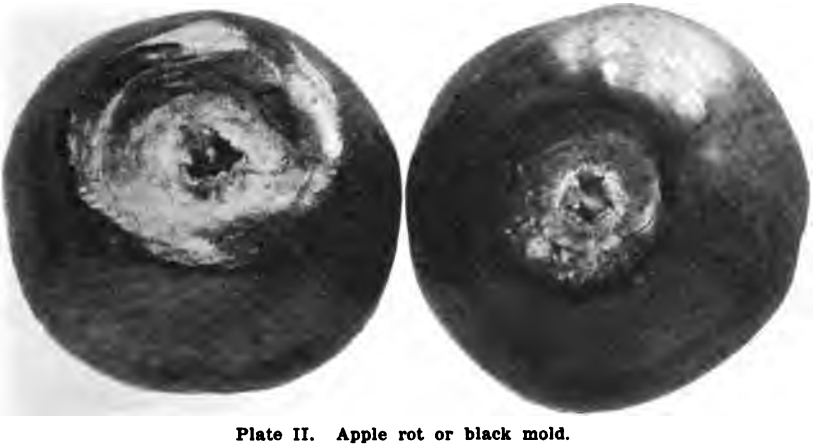

Plate II. Apple rot or black mold.

not greatly softened. In severe cases the apple becomes a shriveled, dark-brown mass. When the apple is placed in storage, the spot increases in size, and sometimes involves the entire fruit. The disease often gains entrance to the fruit by means of wounds. Frequently, no external evidence of the trouble is noticeable, but when

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the apple is cut through, the core cavity and seeds are found to be blackened, and in severe cases the surrounding flesh may be discolored.

Control.—(1) Sanitation. Diseased fruit should be either collected from the ground in the fall, or plowed under. Trees should be kept in good health.

(2) Spray with Bordeaux 4-5-50, or lime-sulfur, just before the buds open in the spring.

(3) Avoid injuring fruit before placing in storage.

CROWN GALL.—Galls may appear on root, stem, or leaf. In orchard fruits, they are most common at the crown, forming there large warty swellings (Plate III). There are two types of galls,

Plate III. Crown gall on a six-year-old plum tree. The warty growth is hard and woody.

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soft and hard. Soft galls usually decay at the end of the season; the harder types may persist for years. Hairy root, a form of crown gall, is characterized by excessive production of fibrous roots.

Control.—(1) Plant only disease-free stock. Burn all infested nursery trees.

(2) Avoid unnecessary injury to plants.

BITTER PIT.—A non-parasitic disease, also known as "Baldwin-spot" and "brown-spot." Spots on the surface are more abundant near the blossom end. They are small, sunken, and various shades of brown. Affected areas may be scattered throughout the apple tissue nearly to the core. The disease may appear before maturity, but develops more often in storage.

Control.—(1) Spotting of susceptible varieties cannot be entirely prevented.

(2) Fruit should be stored in dry air at a low temperature.

JONATHAN SPOT.—The spots, which are distributed over the apple surface, are usually only skin deep, irregularly circular, brown to almost black, and usually somewhat sunken. The disease is not confined entirely to the Jonathan, but develops on other varieties. It is produced only on matured fruit and is most severe in storage and after taken out of storage.

Control.—Cold storage greatly retards development.

POWDERY MILDEW.—This occurs on leaves and twigs. On the leaf, light powdery patches are produced. These are more common on the under surface, but sometimes on both. The patches are small at first, but later increase in size until the entire leaf is covered. In severe cases, affected leaves are crinkled, dwarfed, and drop off. Twigs are stunted or even killed in the worst cases. Powdery mildew does the most injury to nursery stock.

Control.—(1) Cut out and burn infected twigs if the disease is severe.

(2) Spray with Bordeaux mixture or lime-sulfur, immediately after petals fall and later at intervals of two to four weeks, depending upon severity of disease.

RUST.—One stage of this disease is found upon the cedar and another upon the apple. The leaf, fruit, and young twigs of the apple may be affected. The spots on the leaves and fruit are at first about the size of a pin-head, and pale-yellow in color. Later, long cylindrical-shaped organs project from the surface (Plate IV). Fruit may be dwarfed or deformed as a result of the infection.

On the cedar, the diseased condition is known as a "cedar apple." The cedar apple is an enlargement of the leaves and twigs of the ordinary red cedar. These enlargements may be one-half to two inches in diameter. In the winter the gall-like structure is hard

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Plate IV. Pear affected with rust. The appearance of the disease on the apple fruit is similar. Note the long cylindrical-shaped bodies projecting from the surface.

and woody, but in the spring may become swollen and gelatinous. Numerous finger-like gelatinous outgrowths are formed following a rain. Spores from the cedar apple infect the apple, causing the well-known rust upon it.

Control.—(1) Where practicable, remove all cedars in the vicinity of orchard.

(2) Some varieties of apples are comparatively rust resistant, for example: Winesap, Grimes Golden, Yellow Transparent, Ben Davis, Red Astrachan, Duchess, and Maiden Blush. The following are most susceptible: Wealthy, Jonathan, Missouri Pippin, Whitney, and Red June.

APRICOT.

BLACK KNOT.—See Plum, page 37.

CROWN GALL.—See Apple, page 12.

ASPARAGUS.

RUST.—Asparagus rust attacks the tall, branching plants that come up after the cutting season. The plant is hindered in its food-making process, and consequently the underground stems do not receive the normal amount of stored material. As a result, they lack the strength to send up a good crop of "spears" the following spring. The rust appears as small lengthened spots on stems and leaves. The spots look like blisters at first, then they break open

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and appear powdery. The spots that make their appearance in July and August are rusty in color, while those that come in September and October are black.

Control.—(1) Dry sulfur:

a. Use a finely pulverized sulfur, preferably "*flowers* of sulfur," rather than "*flour* of sulfur." ("Flowers of sulfur" is a fine grade that has been sublimed. It sometimes goes by the name of "atomic sulfur." "Flour of sulfur" is a cheaper grade of ground roll sulfur.)

b. Make first application to plants at rate of 150 lbs. per acre, about three weeks after the last cutting of sprouts. Follow with another application at rate of 100 lbs. per acre in about one month.

c. Apply sulfur only in early morning when plants are covered with dew. The sulfur must stick to the plant.

d. On small patches of asparagus, the sulfur may be sprinkled on with ordinary large pepper box. On large patches use some form of bellows-blower.

(2) Spores are carried over winter on diseased stalks and on ground surface. Late in fall, cut and burn the diseased stalks in the field where they have fallen. Further, in order to insure the killing of spores on the ground, put a light covering of straw on the asparagus bed, and burn.

(3) Select disease-resistant varieties. Palmetto is very resistant to asparagus rust.

(4) Plants that have a good supply of water and are well cultivated, and as a result, are making a strong, vigorous growth, are less liable to attacks of rust than plants poorly cared for and deprived of water.

(5) Asparagus escapes from cultivation and frequently becomes common along fences. Unless such stray plants are destroyed, they may be a source of rust infection.

BEAN.

BACTERIAL BLIGHT.—This occurs upon the pod, leaf, and stem of common and Lima beans. The leaves are usually the first to be attacked. At first there appear large, watery patches that are brown in color. Later these patches dry up, becoming papery and brittle. Hence the leaves curl and become ragged in appearance. Pods are most severely attacked. On these, the spots are small at first, but spread rapidly into large, watery areas with indefinite pink or reddish-brown borders. In time, the pods rot. Infected areas on the stem are similar to those on the leaf. The disease is carried over on infected seed. It is spread in the field by insects.

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Control.—(1) Select seed from healthy pods only, grown in fields that are not infected.

(2) New lands should be used when available, and crop rotation should be practiced.

(3) In severe cases spray with Bordeaux mixture, 4-5-50 forula.

a. First spray, when plants are 2 to 3 inches high.

b. Second spray, ten days later.

c. Third spray, after blossoming.

(4) Any measure that will check ravages of insects is advised.

ANTHRACNOSE.—The disease is found on all parts of the bean plant above ground. One is usually attracted by the spots on the pods (Plate V, Fig. 1). These are, at first, small and dark-col-

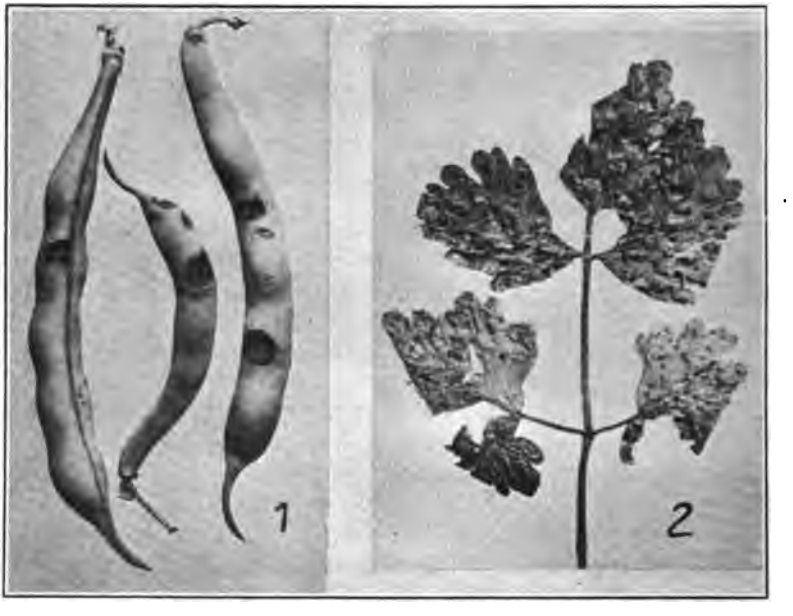

Plate V. Fig. 1. Anthracnose of bean. Fig. 2. Late blight of celery.

ored. They increase rapidly in size up to a quarter-inch or more. Spots may run together and cover the greater part of the pod. They are round or oval, sunken, nearly black, or at times pinkish, and usually surrounded by a reddish zone. On the leaves the spots are found mostly on veins and stem. The spots of the seed are located directly under pod spots.

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Control.—(1) Use seed from healthy pods only, preferably those grown on fields known to be free of the disease.

(2) Burn infected material.

(3) Rotation of crops is important.

(4) Spray with 4-5-50 Bordeaux first, as soon as the plants are up, then about ten to fourteen days later, and again when the pods are forming.

BEET.

ROOT ROT (*Rhizoctonia*).—The outer leaves are first attacked at the base, turn black and droop. The disease spreads into the crown of the beet, which turns brown, cracks, and in time may rot away. The trouble spreads rapidly from plant to plant. Young plants are also frequently attacked by the root rot fungus.

Control.—(1) Keep soil well aired by good cultivation.

(2) Rotate crops.

SOFT ROT.—This is a bacterial disease. The lower end of the root decays, the rotted portion being honeycombed. The cavities of this portion are filled with a rather sticky, colorless, sour-smelling liquid. The upper part of the root, the crown, and leaves, are not affected, and hence the plant maintains a normal color and form above ground. Young plants are not attacked seriously.

Control.—(1) It is useless to spray.

(2) A wet, poorly drained soil favors the development of disease. Improve soil conditions.

LEAF SPOT.—This disease attacks the outer, older leaves first. The youngest leaves in the center rarely show the spots, and the beet plant is seldom killed. At first the spots are tiny white points scattered over the leaf surface. They gradually increase in size, become round, show a distinct line between diseased and healthy portion, and assume a brown color frequently tinged with a red-brown or purple. Still older spots assume an ash-gray center. They are usually distinct, but may become numerous enough to cover the entire leaf. Such a leaf blackens and dies. As the older leaves die, new leaves are formed at the center of the crown. Hence, there is formed an elongated crown with tufts of small green leaves at the top.

Control.—(1) Deep fall plowing and crop rotation is the most satisfactory method of control.

2. Spraying with Bordeaux mixture, 4-5-50 formula, will almost perfectly control the disease, but it is seldom practical. The time for spraying is indicated by the first appearance of the disease. The leaves must be covered thoroughly on both sides.

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(3) A proper and uniform supply of moisture in the soil is beneficial.

(4) If cattle or sheep are used in pasturing the tops, care should be taken that no diseased leaves are scattered to fields intended for beets the following year. Do not allow livestock to enter fields to be used for beets the following year until several days after they have been taken off from the beet-top pasture. The spores of the leaf spot fungus pass through the alimentary canal of cattle uninjured.

(5) Beet tops should be plowed under in the fall, to a depth of ten inches or more.

(6) Manure from stock fed with diseased beet tops should be applied to the land one or two years in advance of the beet crop.

ROOT KNOT.—This trouble is caused by minute worm-like animals (nematodes) which are invisible to the naked eye. It is often mistaken for a fungus trouble. No deformities are produced on the beet above ground. Badly infested plants are dwarfed, wilt easily, and are usually a pale green. In severe cases, the plant may be killed. Galls may form on fine feeding roots, or on larger roots. These enlargements are scattered, or close together and produce abnormal thickening of the root system. In severe cases the roots are a swollen mass.

Control.—(1) Rotation of crops. Cultivate immune crops for two or three years. Kill all weeds and other plants in which the worm-like animals live. Plants not attacked are barley, corn, broom corn, millet, red top, rye. sorghum, timothy, wheat, and winter oats.

(2) Prevent running water, implements, animals, etc., from bringing the nematodes from near-by infested fields.

(3) Starving the parasite by keeping the land free from all vegetation for two years is an effective control method, though often impracticable.

CROWN GALL.—The crown gall of beet is caused by the same organism which produces galls of the apple. The characteristic swellings or galls may be produced upon any portion of the beet root. See crown gall on apple.

Control.—Rotation is the only effective remedy if the bacteria once gets into the soil. Plants which are not attacked, like the grains or grasses, should be used in the rotation.

BLACKBERRY.

LEAF SPOT.—Diseased spots are small and numerous. They have a white or ashy-gray center, bordered with a brown or reddish ring. In later stages, minute black specks may cover the center of

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each spot. This disease is not very common and epidemics are rarely developed.

Control.—See anthracnose of currant.

ORANGE RUST.—See Raspberry, page 45.

ANTHRACNOSE.—See Currant, page 29.

CABBAGE.

CLUB ROOT.—This is an uncommon disease in Colorado. It occurs on cabbage, radish, turnip and other members of the mustard family. The roots of the infected plants become greatly swollen and contorted, usually forming a cluster of finger-like or spindle-shaped swellings. Wilting of the plant results, particularly on hot days, although in the early stages of the disease such wilted plants may recover at night. Later, the plant succumbs or forms only a small head. The organism causing the trouble is in the soil and first attacks the young roots.

Control.—(1) The disease may be carried from field to field in the soil on the feet of horses, or on cultivators. Diseased plants thrown on the manure pile or compost heap may subsequently reach the field. Precautions should be taken to burn all affected plants.

(2) Rotation of crops.

(3) Destruction of weeds of the mustard group that may harbor the fungus.

BLACK ROT.—This is a bacterial disease. Infected plants are dwarfed, and often one-sided. In severe cases the entire head fails to develop or the plant dies. A black ring, corresponding to the woody part of the stem, is found in cross-sections of affected stems. This blackened tissue often can be traced up into the head. Infection takes place at the leaf margin or about insect wounds. The leaf veins become blackened as the disease progresses. The tissue between the leaf veins turns yellow and then brown. Affected leaves dry up and drop prematurely, thereby producing an elongated stem covered with leaf scars. Diseased leaves pulled from the stem show blackened bundles in the leaf stalk.

Control.—(1) Disinfect the seed, before sowing, in corrosive sublimate, 1-1000, for fifteen minutes, or in formalin, 1-200, for twenty minutes.

(2) Prepare seed-bed with manure and soil that is free from diseased refuse.

(3) Crop rotation is very important. No cultivated crucifers or cruciferous weeds should be allowed to grow in the ground for four or five years after a bad attack.

(4) Keep down insects, slugs, snails. etc., for they spread the disease from plant to plant.

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(5) Do not allow livestock to roam over infested fields, for they carry the organisms to non-infected fields.

(6) Diseased plants should be pulled up and destroyed.

CANTALOUPE.

LEAF BLIGHT OR "RUST."—This disease is more properly termed "blight." The name "rust" is suggested by the rusty appearance of the leaves due to the numerous brown spots with which they are covered. These spots are circular; they first appear on leaves in the center of the hill. They may enlarge as the disease progresses, and several may run together, causing a curling and death of the leaf. Frequently the disease occurs on stems. Moist weather favors the spread of blight. Affected plants ripen their fruit prematurely, thus destroying the flavor.

Control.—(1) Use resistant varieties.

(2) Rotation of crops. This is highly advisable.

(3) Spray with 4-5-40 Bordeaux, first when the vines begin to run, followed by 1 or 2 more at intervals of 10 to 14 days.

CARROT.

SOFT ROT.—This is a bacterial disease which causes a soft rot of many vegetables. Decomposition usually begins either at the crown or root tip, and progresses rapidly through the core. Bacteria enter the fleshy tissue through wounds. Lengthwise sections of diseased roots show a softened, watery, decayed portion which is usually brown. There is a sharp line of division between the decayed and sound tissue.

Control.—(1) Treatment must aim entirely toward prevention.

(2) Rotation of crops is advised, with such crops as the grasses, cereals, etc.

(3) Use manure that is free from refuse of diseased plants.

(4) Dry the root surface before storage. The roots should be left on the surface of the ground, exposed to the sun, a few days before storage. Store in a dry and well ventilated place. The organism cannot endure drying nor can it invade dry tissue.

(5) Cold storage is advised at a temperature between 39 and 50 degrees F. This temperature, coupled with the disinfection of the root surfaces by drying and sunlight, should prevent serious injury from the rot.

CELERY.

BLIGHT.—There are two distinct blights of celery, *early blight* and *late blight*. Both diseases are due to fungi which feed upon the leaves, and in some cases the stems. The organisms causing the two diseases are entirely different. The effects of, and the remedial measures for the two are similar, however.

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Early blight may make its appearance in the early stages of the plant's growth, either in the seed-bed or in the field. The outer leaves are first attacked; grayish-green spots, roughly circular in outline and with slightly raised borders, appear. Later the spots become darker in color, an ashen-gray, and larger. In some cases several adjacent spots may run together. Finally the entire leaf withers and dies. When the spots become brownish, it is an indication that they are producing reproductive bodies, the spores. These are readily blown from plant to plant, and in this way the trouble is spread throughout the field.

Late blight, in general appearance, resembles early blight (Plate V., Fig. 2). It may follow early blight in the same field and its effect upon the marketable value of the celery plant is similar. As compared with the early blight, the spots on the leaves are more irregular, and yellowish in color rather than ashen-gray. The spots later become covered with small, black fruiting bodies. These are readily seen with the hand lens. Late blight is found in the field until the plants are lifted and commonly continues its destructive work in storage. In fact, often the worst damage to the celery crop from late blight comes while the plants are in storage.

Control.—(1) Do not set plants from the seed-bed that are the least spotted.

(2) Dip leaves of all transplants in a weak solution of ammoniacal copper carbonate.

(3) Keep the plants in as vigorous condition as possible from start to finish. This is important.

(4) Remove and burn all diseased leaves, if practicable, as fast as they appear, so as to prevent further spread of the disease.

(5) Remove and burn all celery debris from the celery plot in the fall; this debris may harbor the spores which will live over the winter to infect young plants the following spring.

(6) Spray with ammoniacal copper carbonate, or 5-6-50 Bordeaux mixture, first when the plants are in the seed-bed, following with treatments at two or three week intervals throughout the growing season.

(7) In the case of late blight, dip only the leaves of lifted plants into ammoniacal copper carbonate before placing in storage.

(8) Do not store plants that show any spotting.

(9) The celery leaf spot disease may be spread by the use of affected seed. To render the seed safe, soak them three hours in formalin solution (1 pint 40 per cent formalin in 70 gallons of water). Thoroughly dry seed before planting.

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CEREALS.

RUSTS.—The cereal rusts are too well known to need description. They occur on both stems and leaves, and in many instances cause serious injury to the crop.

Control.—There are no satisfactory, practical methods of control. Some varieties are more rust-resistant than others. It appears that plants growing on soil that is well-drained are more resistant to rust than plants on poorly-drained soil.

BARLEY.

COVERED SMUT.—Smut masses enclosed by thin covering, which breaks open soon after heads appear. Smutted grains ("smut-balls") often occur in threshed grain. Chaff as well as grain is smutted. Spores are blown from infected heads to healthy grain. These spores remain over winter on the outside of the healthy grain.

Control.—Use the formalin sprinkle as given under bunt of wheat.

LOOSE SMUT.—Smut masses not enclosed for any length of time by thin covering. As soon as smutted heads appear, the spores are scattered by the wind, and nothing but the bare stalk of the head remains. "Smut-balls" not formed. Smut mass olive-green in color. Appears earlier in season than covered smut. It is the more common sort of barley smut with us. Infection of sound seed always takes place before harvest time. The smut is carried over within the seed, not on the outside, as in the case of covered smut of barley.

Control.—Use *hot water* method as described under loose smut of wheat. *Note*: In the case of barley, the water in Tub No. 2 is kept exactly at 125 degrees F., and the grain is left in it 15 minutes.

WHEAT.

STINKING SMUT, OR BUNT.—Bunt is the most destructive smut of wheat. It is more common than loose smut of wheat. Bunt is exclusively a kernel smut. The contents of the grain of wheat are entirely replaced by a powdery mass of black spores. The spore mass or "smut-ball" is rather hard. Bunt usually is not noticed until the heads are mature. As a rule, all grains of a head, and all heads of an infected plant are smutted. Smutted grains, as compared with healthy ones, are darker in color, lighter in weight, plumper, and more easily crushed. When the smutted grain is crushed, numerous black spores are liberated, and the grain gives off a characteristic decayed fish odor. The spores get on healthy grain usually at threshing time; the smut-balls are

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crushed in the thresher. A few broken smutted seeds can contaminate a large amount of healthy grain. Spores are carried from farm to farm by threshing machinery, and by wind. Bunt affects both spring and winter varieties of wheat. The spores of bunt will not cause smut in oats, barley, corn, or sorghum. The smuts of these cereals are distinct.

Control.—The object of seed treatment is to kill all bunt spores clinging to the outside of healthy grains. Bunt spores are carried into the ground with the grain of wheat, the young seedling is infected and at maturity the heads of the plant are smutted. Before treating seeds with formalin, place them in a tub or barrel of cold water, and stir. The lighter smutted grains will come to the top and may be skimmed off. Smutted seeds may also be fanned out with a good fanning mill. The easiest and most efficient seed treatment is the *formalin sprinkle.* This is done as follows:

(1) Formalin is a solution of formaldehyde gas in water. It usually has a concentration of about 40 per cent. Ask for this strength. Formalin may be obtained of any druggist. Put 1 pint (1 lb.) of formalin in 45 to 50 gallons of water. Stir thoroughly. Use this material when fresh; it deteriorates with standing.

(2) Put seed wheat to be treated on clean, hard barn floor, or in wagon box, or on canvas. The floor, wagon box, or canvas should be cleaned with a strong formalin solution, or with boiling water. Spread grain out a few inches deep.

(3) Sprinkle solution over grain with ordinary garden sprinkling can. Use about 1 gallon of solution to each bushel of grain.

(4) Shovel grain over and over. One person can handle the sprinkler while another thoroughly mixes the grain.

(5) Shovel treated grain into a pile and cover with canvas or gunny sacking that has previously been dipped in formalin solution or boiled in water. Leave covered for 2 or 3 hours.

(6) Spread grain out not more than 2 inches deep and allow to dry.

(7) Treated grain, if not planted directly, should be kept in smut-free sacks or bins. Disinfect sacks or bins with strong formalin solution or boiling water. Drills may be disinfected by washing out with strong formalin solution.

LOOSE SMUT.—The entire head of wheat is affected and turned into a powdery mass. It is earlier than bunt, and the smut-masses break open immediately after the head appears. At harvest time only bare stalks of diseased heads remain. The smut-mass has no odor. Smut-balls are not formed. Sometimes only a part of the grain-head is affected; in such cases it is always the lower part. Infection of sound seed always takes place before harvest time. Seed

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that is apparently sound may carry the smut fungus within. Loose smut is carried over within the seed, not on the outside, as in the case of bunt.

Control.—The object of seed treatment is to kill the smut fungus that may be within apparently healthy grain, and at the same time not injure the germ. The formalin treatment is worthless. It is also needless to try and remove affected seed by placing seed wheat in cold water, or by fanning it. If you do not treat your own grain, be careful to get seed from a field that is smut-free. With considerable care, seed with loose smut of wheat may be treated successfully, by use of *hot water method.* This method is as follows:

(1) Soak grain for 5 or 6 hours in cold water. Use small quantities of grain (about 10 lbs.), placed in coarse sacks.

(2) Remove grain, in sacks, to tub or barrel No. 1, in which the temperature of the water is about 110 to 120 degrees F. Keep the grain in this 1 or 2 minutes. *Use good thermometer.*

(3) Remove grain to tub or barrel No. 2, in which the temperature of the water is kept *exactly* at 129 degrees F. Leave grain in this 10 minutes.

(4) Spread seed out to dry.

(5) In the above process some seed is killed. Hence it is necessary to increase the amount of seed used per acre. The extra amount of seed can be determined by comparing treated and untreated seeds when tested for germination.

OATS.

BLADE BLIGHT.—This is a bacterial disease which at first causes yellowing of the leaf. Diseased portions on the leaf are either round, or long and streak-like. The trouble usually begins at the tip of the leaf and works down into the plant. It may, however, start on the lower portion of the plant. In advanced cases the leaves collapse and take on a mottled reddish color. The leaves often crack and there appear droplets of a sticky fluid on their surface. At first this fluid is yellowish, but later it turns brown.

Control.—No control has been found.

LOOSE SMUT.—The common smut of oats is the loose smut. It appears as soon as the plant begins to head. As a rule, all heads on smutted plants and all grains on smutted heads are affected. Chaff as well as grain is smutted. Smut spores are early blown away by the wind, leaving the oat stem bare. Spores are carried over winter, clinging to the outside of healthy grains.

Control.—The formalin sprinkle as described under bunt of wheat is entirely satisfactory. It is unsafe to use bluestone (copper sulfate) in treating oats for smut.

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CORN.

SMUT.—The appearance of corn smut is well-known. Black smut masses usually appear on the ears, but also frequently on tassels, leaves, and stems. Black spores are produced in tremendous numbers and scattered broadcast by the wind. Spores may live in the soil or in the manure pile. The spores that rest over the winter, in the spring produce spores of another type, and it is these new spring or early summer spores that infect the corn plant. Any part of the corn plant may be infected. Hence seed treatment is useless.

Control.—(1) The formalin sprinkle and hot water treatments are useless. Corn smut cannot be controlled by any form of seed treatment.

(2) Corn smut spores may pass through the digestive tract of animals without destroying their germinating power. Furthermore, the spores may actually grow and reproduce in fresh manure. Use well rotted manure, as it contains few or no living spores.

(3) Remove and burn all smut masses from field before they discharge the spores.

(4) Since spores may remain alive in the soil several years, crop rotation is of value. Any other crop than corn may be used in the rotation, for corn smut spores cannot cause smut, or be carried over, in any other plant.

SORGHUMS.

SMUTS.—Under the name sorghum are included milo, kafir, feterita, durra, kaoliang, broom corn, Sudan grass, and shallu. There are two smuts of the sorghum, kernel smut and head smut. In kernel smut of sorghum, each kernel becomes a smut mass, and the head retains its usual shape. The disease appears early in the season. The formalin sprinkle is an entirely efficient treatment for sorghum kernel smut. It is the more common sorghum smut.

In head smut of sorghum, the entire head becomes a large deformed smut mass. It is a loose smut. The life history of this smut is not well understood. Seed treatment is probably of no use. Cut out and burn infected plants. Rotation of crops may be of advantage. Milo is not attacked.

SUMMARY OF TREATMENTS OF CEREAL SMUTS.

1. Use the formalin sprinkle for:
   - (a) Bunt or stinking smut of wheat.
   - (b) Covered smut of barley.
   - (c) All smuts of oats.
   - (d) Kernel smut of sorghums.
   - (e) Smuts of millets.

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2. Use the hot water treatment for:
   (a) Loose smut of wheat.
   (b) Loose smut of barley.
3. Seed treatment is useless for:
   (a) Corn smut.
   (b) Head smut of sorghums.

CHERRY.

SHOT HOLE.—This disease is evidenced by leaf spots, which are brown, circular, and with margins that may or may not be sharp (Plate VI). Shot-holing may be caused by the diseased portion falling out. In severe cases large numbers of spots appear in a cluster causing the whole leaf to assume a yellow color and fall.

Plate VI. Shot-hole of plum.

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This disease must not be confused with spray injury. Fruit and fruit stems are rarely attacked.

Control.—(1) Spray with self-boiled lime-sulfur, 8-8-50: atomic sulfur 5-50; commercial lime-sulfur 1¼-50; or Bordeaux mixture, 4-5-50 formula.

(a) First when petals fall, beginning when they are three-fourths off.

(b) Ten days to two weeks later.

(c) Three to four weeks before fruit is harvested.

(d) In sections, subject to severe attacks, an application should be made just after the fruit is picked.

(2) If possible, dispose of fallen leaves by fall or spring plowing.

BLACK KNOT.—See Plum, page 37.

CROWN GALL.—See Apple, page 12.

CUCUMBER.

BACTERIAL WILT.—This is evidenced by a wilting of the leaves and runners. There is no indication of injury to the roots, such as blackening, or to the leaves and stems, such as spotting. The leaves even retain their green color for quite a time. The water tubes are plugged, thus causing a wilting. By squeezing an infected runner, there oozes a sticky, milky, stringy liquid. This wilt also occurs on the Hubbard squash and cantaloupes.

Control.—Practice crop rotation.

(2) Insects are important agents in the spread of the disease. Spray for squash bug and cucumber beetle.

(3) Remove and burn affected parts promptly.

DOWNY MILDEW.—This disease is found on almost all cultivated species of the gourd family, such as cucumbers, muskmelons, watermelons, squash, and pumpkins. Affected leaves have irregular yellow spots, which run together in serious attacks causing the entire leaf to yellow, shrivel, and die. A whitish downy mass tinged with purple can often be seen on the under side of the large older spots. In weather unfavorable to the disease, the spots remain small. The disease starts with older leaves, and spreads toward the ends of the vines. Hence the center of the hill is first killed. Very few cucumbers are produced on diseased vines.

Control.—(1) Spray with Bordeaux mixture, 4-5-50 formula.

(a) First application, when the vines begin to run.

(b) Later sprayings, at intervals of about ten days, if the weather is dry, and oftener if the disease spreads rapidly.

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POWDERY MILDEW.—A common disease attacking all parts of the cucumber. This trouble has the general characteristics of all powdery mildews. At first the diseased stems are covered with whitish, powdery, circular spots. Later, these spots spread and may cover the entire leaf, which becomes distorted and retarded in its growth. Infection is found mostly on the upper surfaces, and on older leaves. Stems are similarly attacked. Blossoms attacked fail to set their fruit. Diseased fruits develop the same symptoms as leaves. Such fruits become distorted and bitter.

Control.—(1) Apply flowers of sulfur with a good dust sprayer. The sulfur must be distributed to every part of the plant. Vines should be sulfured 1 to 7 times.

(a) First application, when the shoots are a foot long.
(b) Second application, at the first sign of the mildew.
(c) Later applications, as need indicates and according to the weather. Less sulfuring is necessary during hot, dry weather.

CURRANT.

CANKER OF CANES.—This disease has become prevalent in certain sections of the state. Apparently healthy canes may bear the fungus, which causes the trouble, for several years. The first indication of the disease is yellowing of the leaves and early coloring of the fruit. Positive evidence of the presence of the canker in a patch of currants is the appearance of pinkish, cushion-like masses on dead canes (Plate VII).

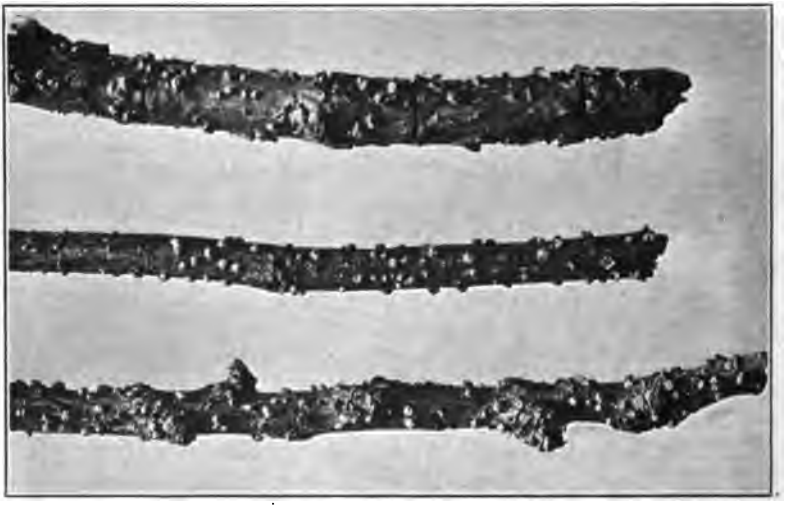

Plate VII. Canker of currant canes. The cushion-like bodies seen scattered over the canes are pinkish in color.

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Control.—(1) Cut out and burn all diseased plants as soon as the trouble appears in the spring.

(2) All cuttings for planting should be made from stock that is known to be healthy. Do not even take cuttings from plants that appear healthy when such plants stand in a plantation known to have diseased plants.

(3) Spraying is not recommended.

CURRANT LEAF SPOT.—Diseased spots are about one-eighth of an inch in diameter and more or less angular. They have grayish centers with brown borders. Minute black specks may be seen on older diseased areas within the grayish center. Spots may be few or numerous. In the latter case, the leaf turns yellow and falls. Serious defoliation may result. This spot is easily distinguished from the anthracnose leaf spot by its larger size, its well-defined area, and its gray center, usually with black specks. Anthracnose leaf spots are black and small.

Control.—See anthracnose of currant.

ANTHRACNOSE.—This disease attacks fruit, fruit-stems, new canes, leaves and leaf stalks. Newly developed spots on the berries are rather noticeable. As the berries ripen, spotted fruits are less conspicuous. This is probably because the worst affected fruit has dropped. The spots on fruit are black, circular, and resemble fly specks. Affected berries do not rot or wither. Spots on the fruit-stems are black, and slightly sunken. They are from one-fourth to one-half of an inch in length and extend half way or more around the stem. Spots on new canes are rather inconspicuous. They are pale yellow or light brown, therefore almost the color of the cane. A slight discoloration of the bark is produced. The lower leaves are attacked first. They become thickly covered with small, dark brown spots. Affected leaves turn yellow and fall. Spots on the leaf-stalk are conspicuous. They are black and slightly sunken. Diseased plantations are easily recognized by the yellow color of the foliage. At ripening time the diseased leaves fall, leaving the vines bare, and exposing the red fruit.

Control.—(1) Spray with Bordeaux mixture, 4-5-50 formula, or lime-sulfur, 1 to 50.

(a) First application, made on bare canes before the leaves appear.

(b) Second application, made while the leaves are unfolding

(c) Later applications, at intervals of from two to three weeks, until the fruit is two-thirds grown.

FLAX.

WILT.—The cause of flax wilt is a fungus which grows on the inside of the flax plant. It is found that the roots of diseased plants

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are chiefly affected. Flax wilt may live over in the soil from year to year. Plants of all ages may be attacked. They wilt and die as from lack of water. The disease may spread very rapidly.

Control.—(1) Flax is being grown for the first time in many sections of the state. Since the spores of the fungus causing wilt may be carried by the seed, it is particularly important that clean seed be used, to prevent the introduction of the disease to the soil. Disinfect seed with formalin. This treatment is as follows:

(a) Make solution of formalin at the rate of 1 pound to 40 gallons of water.

(b) Spread seed upon a clean canvas or good tight floor.

(c) Sprinkle a small quantity of solution upon the seed. At the same time, rake the seed about. Take pains that all seeds are moistened, but do not use so much of solution as to cause the seeds to stick together. There is danger from using too much moisture. Use about ½ gallon of solution to each bushel of seed.

(d) Allow the seed to stand for several hours, covered by a canvas, then rake and stir until thoroughly dry.

(2) Fanning seed before treatment will remove many light weight infected seed.

(3) Store flax seed in dry place. The fungus grows on moist seed.

(4) The wilt fungus is held over in old flax straw and stubble. Hence remove and burn infected flax straw and refuse.

(5) Do not use manure made from infected flax straw. Well composted manure will contain no spores capable of germination.

(6) If wilt becomes bad, plant infected land to some other crop.

(7) Use disease-resistant varieties.

GOOSEBERRY.

MILDEW.—English varieties of gooseberries suffer more from the attacks of this fungus than American sorts. The frost-like coating of the parasite appears on stems, leaves, and fruit. The whitish, cobwebby growth becomes darker in color later in the season, and careful examination with a hand lens will show the presence of numerous black specks over the entire diseased surface. The black bodies carry the spores.

Control.—(1) Spray with potassium sulphide, 1 oz. in 2 gallons of water. Apply first spray just when the buds begin to open. Follow this with sprayings at intervals of about 14 days until the fruit is ready to pick.

(2) Establish good circulation of air about the plants by cutting out the lower drooping branches.

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LETTUCE.

LETTUCE DROP.—The first indication of the disease is a sickly plant. Later the outer leaves wilt, one after the other, and fall flat upon the ground. Finally, water-soaked areas are produced over the stem, and the whole plant falls over and rots away. Such plants show a cottony growth on the under side of affected leaves. In the last stages of the disease, many small black bodies may be formed upon the affected portions.

Control.—(1) Remove and burn all diseased plants as soon as they appear.

(2) Spray the place where the infected plants stood, either with Bordeaux mixture, 4-5-50 formula, or with bluestone dissolved in water at the rate of one pound to seven gallons of water, or with weak formalin.

(3) Guard against introduction of the trouble in refuse or compost which may contain diseased lettuce plants.

(4) Rotation. Do not follow lettuce with celery, or celery with lettuce, as both crops are subject to the disease.

(5) Set out healthy plants only.

(6) Soil steaming or sterilization is practicable for lettuce grown under glass.

ONION.

BLIGHT OR MILDEW.—In a few of the truck growing regions of the state, this disease has been rather serious. It makes its appearance the latter part of June or first part of July. Damp weather or excessive irrigation favors its development. It is possible to recognize the disease in its very young stages. Early in the morning, when there is moisture on the leaves, infected leaves have a peculiar, furry, violet tinge. Later on, they become covered with a white mildew-like growth, and finally collapse. As a result of the leaf infection, the onion bulbs do not reach their proper size.

Control.—(1) In case of serious outbreak of disease, spray with 4-5-50 Bordeaux mixture. Apply this from time to time until disease is checked.

(2) The disease is carried over the winter on dead onion leaves. Care should be taken to rake and burn all the tops.

(3) In case the disease has been serious for several successive years, it may be well to practice crop rotation, not going back to onions until three or more years.

PEA.

POWDERY MILDEW.—This disease is prevalent in the state on both garden and field peas. It is readily recognized by the white cobwebby growth on both surfaces of the leaves. Moist weather,

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over-irrigation, and crowded condition of plants favor its development.

Control.—(1) Bordeaux mixture readily controls it. It is seldom a practical remedy, however, as the disease is not often severe enough to warrant the expense.

(2) Keep soil well-drained.

(3) Do not overcrowd the plants.

(4) Early crops are not as liable to attacks of fungus as late crops.

PEACH.

SCAB.—The disease is found on fruit, leaves, and twigs. It is also known as "black spot" and "freckles." Spots on the fruit are about ⅛ of an inch or less in diameter, dark brown to blackish, and nearly circular. Diseased areas are found only on the surface and may be slightly depressed when many spots come together. Frequently, individual spots crack. If a mass of spots come together, producing a "smutty" or blackish appearance, the peach cracks open and shrivels. Infection is most abundant about the stem attachment and weather side of fruit. On the leaf the spots are nearly circular and are formed only on the surface. They are pale green in early stages and a yellow-brown or purple in later stages. Wood of the current season may be attacked.

Control.—(1) The disease is very easily controlled by spraying. Spray with 8-8-50, self-boiled lime-sulfur, about one month after the petals drop and again three or four weeks later.

BLIGHT.—This disease occurs on fruit, leaves, and stem. The spots on fruit are irregularly oval to circular. At first, they are pink, but later become typically brown with a pink outer ring. These spots are slightly raised and found only on the surface Gumming is not abundant on diseased fruit. Badly infected fruit is shed early. On leaves the spots are irregularly circular and reddish to brown in color. Spots may fall out, causing shot-holing. In severe attacks, defoliation may take place. On twigs the spots are irregularly oval in shape. At first they are reddish, but later become brown to black, and often sunken. Gumming is generally conspicuous on diseased twigs. Buds on the fruiting wood are killed.

Control.—Spray in the fall with Bordeaux mixture, 4-5-50 formula.

POWDERY MILDEW.—The leaves, twigs, and fruit are attacked. White irregular blotches are produced on the leaves, mostly along the midrib. In the shade, both leaf surfaces are affected. The leaves crinkle, curl, and in severe cases the younger ones near the tip fall. White blotches are formed on diseased twigs (Plate IX).

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Plate VIII. Peach fruit attacked by powdery mildew.

Plate IX. Peach twigs attacked by powdery mildew.

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The bark under these blotches becomes dry and brown. In severe cases the bark shrivels and the young tips often curve or are killed outright. Spots on fruit are at first musty or frost-like patches which later become almost pure white (Plate VIII). The skin under the spots becomes brown and the flesh becomes hard. The entire crop is often ruined for market.

Control.—(1) Plant trees far enough apart to allow free circulation of air. This tends to prevent development of mildew.

(2) Open head system of pruning is to be preferred.

(3) Spray with lime-sulfur solution, 1-50, with or without 3 pounds of iron sulfate added to 50 gallons of the mixture. Addition of iron sulphate increases covering and sticking qualities.

(4) Dusting with flowers of sulfur is also effective. This can be easily done with a dusting machine. The sulfur should be applied as early in the morning as possible while the dew is still on the foliage.

Applications for lime-sulfur or sulfur treatment:

(a) First application, made as soon as the disease appears and before it has become thoroughly established.

(b) Later applications, made at intervals of 9 days or oftener, according to the severity of the disease. One or two applications may be sufficient while in some seasons five or six applications are necessary.

PEAR.

FIRE BLIGHT.—Fire blight of the pear, apple, quince, apricot, and plum attacks blossoms, twigs, limbs or body, and fruit. The blight attracts special attention two or three weeks after the blossoming period. The fruit spurs at first shrivel, turn brown, and then black. Blight works down the twigs and branches into the trunk or body of the tree, often causing the destruction of the entire tree. The affected portion is somewhat sunken, dark in color, usually with a brownish tinge. In spring the diseased bark may be slightly blistered, and here and there drops of a clear, slimy liquid may collect. Later in the season, when the progress of the blight is checked, the infected bark shrinks, becomes smooth, and forms a definite line of division between diseased and healthy tissues. The trouble is seldom found on mature fruit. Hold-over canker on twigs is shown in Plate X.

The disease is caused by a bacterium which is spread chiefly by insects.

Control.—(1) Spraying the trees with a fungicide is not effective.

(2) A number of blight remedies have been placed on the market by manufacturers. They are supposed to make the trees im-

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Plate X. Hold-over canker of pear twigs. Note the cracks from which the oozing takes place.

mune by the introduction of a fluid into the sap. These have not been proven successful.

(3) Strict sanitation and eradication methods are the most satisfactory means of control.

(a) All sources of infection should be destroyed. This can best be done by removing all diseased portions in the autumn after the leaves have fallen. Affected branches should be cut back from ten to fifteen inches below the discolored wood. Cankers in crotches should be scraped down to live wood, and disinfected.

(b) Trees should be inspected in early spring, and all cases of blight removed and burned. A weekly inspection of all trees during the growing season should be carried on as soon as the blossoms fall, and all cases of blight removed and burned.

(4) Tools as well as all cuts should be disinfected with corrosive sublimate, 1-1,000, so that bacteria are not spread.

(a) The corrosive sublimate may be carried in a bottle or wooden pail, and applied to the wounds and tools with a sponge.

(5) Collect diseased material in a sack; the sack may be strapped to the operator for convenience. Burn all affected material.

(6) A systematic and continuous fight in cutting and destroying diseased portions is essential for successful control.

(7) Disease is spread by insects. Hence keep these down by spraying with a good insecticide.

(8) The native thorn apples and mountain ash are a host for the organism causing fire-blight. Trees in the immediate neighborhood should be destroyed.

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(9) Avoid heavy winter pruning, as it produces heavy succulent shoots subject to attacks of bacterium.

CROWN GALL.—See Apple, page 12.

RUST.—See Apple, page 13.

PLUM.

PLUM POCKETS.—The disease is present on fruit, twigs, and leaves. First evidence on the fruit is yellowing. The fruit then enlarges rapidly, attaining a size several times the normal. The surface becomes deeply wrinkled, and the pit fails to develop, having in its place a large air cavity (Plate XI., Fig. 2). The diseased

Plate XI. Fig. 1. Black knot on plum. Fig. 2. Plum pocket, showing the enlarged, darkened, diseased fruit.

fruit later turns brown, shrivels, and falls, or in some cases remains on the tree. Diseased twigs are enlarged, deformed, and usually somewhat curved. In later stages the twig turns brown. Infected leaves are abnormally thickened and deformed. Later they shrivel, become brown, usually remaining on the tree.

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Control.—Affected branches and badly affected trees should be destroyed.

FIRE BLIGHT.—See Pear, page 34.

CROWN GALL.—See Apple, page 12.

SHOT HOLE.—See Cherry, page 26.

BLACK KNOT.—Early evidence of infection is indicated by a slight swelling of the branch. This is followed by a rapid increase in size. The knot attains its full size in 10 to 12 days. As growth increases, the bark ruptures and exposes a granular olive-green growth. Later this mass turns black (Plate XI, Fig. 1). Knots vary as to size and shape, some being only a quarter of an inch in length, while others attain a length of five or more inches. As a rule, they do not encircle the entire branch. Diseased twigs are often curved. The knots persist on old twigs and the next year they produce new knots. Old knots remain on trees for 5 or 6 years.

Control.—(1) All knots should be removed, by cutting at least 6 inches below the diseased portion, and destroyed.

(2) Spraying with Bordeaux mixture, 4-5-50 formula, just before the buds open, has been recommended.

POTATO.

EARLY BLIGHT.—This potato trouble is not prevalent in Colorado. The leaves become spotted in July or August, about the time the blossoms appear. The small brown spots are surrounded by concentric rings, which give them a very characteristic appearance. The spots may run together, causing withering and death of the entire leaf. As a result of the leaf affection, tubers do not develop normally. The tubers, however, are not diseased.

Control.—(1) Spray with Bordeaux mixture. This should be done at intervals of about two weeks. The first application is made before the appearance of the disease.

(2) Plant resistant strains.

(3) Maintain the vigor of the plant by proper methods of cultivation.

SCAB (OOSPORA).—This "Oospora scab," so prevalent in eastern states, has never been serious within the state. The most common scab on potatoes in Colorado is due to another fungus—*Rhizoctonia.* "Oospora scab" is a surface disease of the tubers. The fungus produces a roughened, pitted, scabby surface (Plate XII). It also occurs on beets, cabbage, and other plants.

Control.—(1) Use smooth, scab-free tubers for seed.

(2) Disinfect seed potatoes. Soak the tubers for two hours in formalin, 1 pound (pint) in 30 gallons of water.

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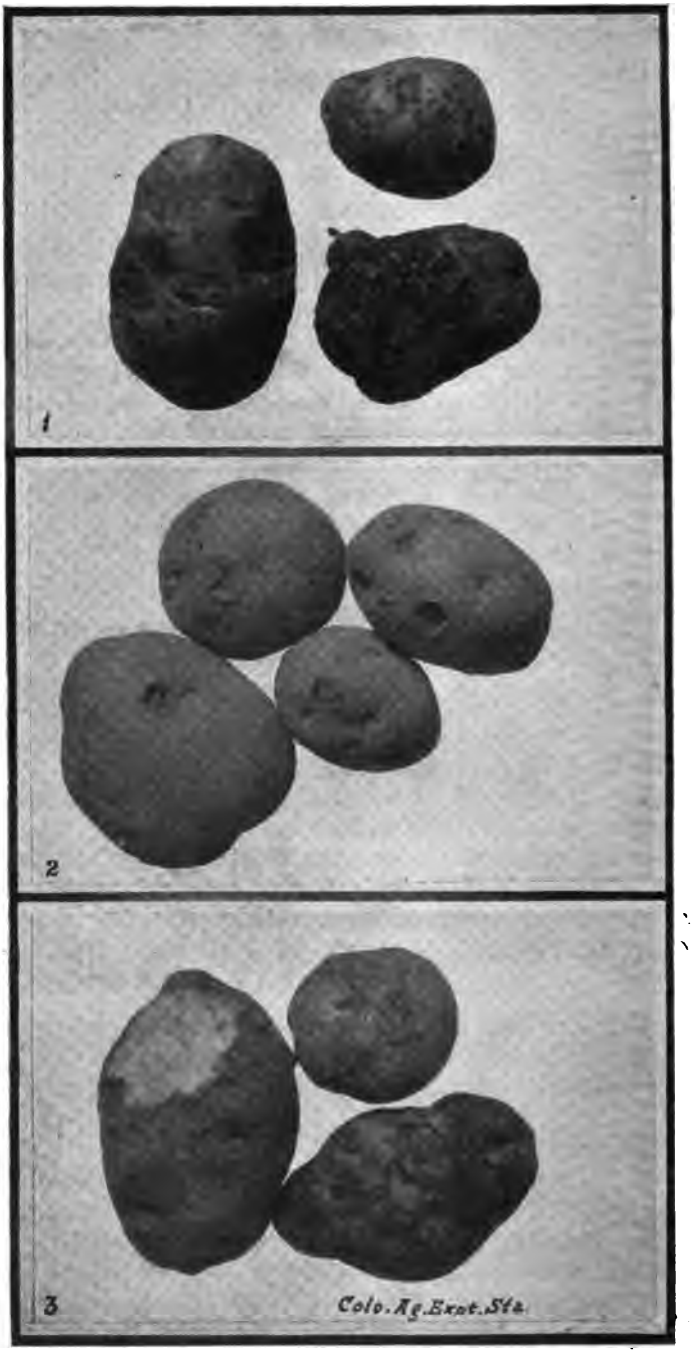

Plate XII. Scab of potatoes. Fig. 1. Surface scab. Fig. 2. Deep scab. Fig. 3. Scab produced by beetle.

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(3) The spores of the fungus are uninjured in passing through the digestive tracts of livestock, and hence reach the field in the manure. Do not feed uncooked scabby potatoes to livestock.

(4) If the disease becomes prevalent in a soil, practice crop rotation, not returning to potatoes for 4 or 5 years.

FUSARIUM WILT OR BLIGHT.—The serious reverses that potato growing has undergone the last few years in Colorado have been ascribed to *Fusarium* wilt or blight. That it is the only cause of the epidemics is doubtful. However, it is quite certain that it is largely responsible.

In regard to the symptoms of *Fusarium* wilt, we quote from Professor B. O. Longyear, of this station:

"This trouble first manifests itself in the field by the wilting and yellowing of the lower leaves of plants that have reached the height of ten to twelve inches. In bad cases the entire foliage appears to suffer as though the plant were not getting sufficient moisture. Later on, the tips of the leaves turn brown and dry up, leading to the trouble commonly known as 'tip burn.' The edges of the leaves commonly roll inward during the heat of the day, although they may partially revive during the night.

"Badly affected plants will be found to have the root hairs and rootlets rotted away and often the larger roots appear sickly. Cross-sections of the main root often appear brownish in the region of the vascular bundles or woody part. Under the microscope thin sections of such roots and of the lower part of the stem will show the delicate filaments of the fungus which pass upward through the water-conducting tubes of the plant and eventually clog them to such an extent that the flow of sap is greatly obstructed. This is what causes the wilting and eventual drying of the foliage of the plant.

"The fungus also passes into the tuber-bearing stems under ground and frequently enters the stem end of the tuber for some distance. In bad cases the stem end of the tuber may be rotted away and the presence of the fungus deeper in is indicated by the browning of the vascular ring shown in a cross-section of the tuber. The fungus may also enter the tuber from the soil through any bruise, crack, or other break in the skin. Attacks of insect larvae upon the tubers are often followed by this disease through the wounds which the 'worms' produce.

"Under conditions of plenty of moisture and high temperature, this disease makes it most rapid progress and may reach its culmination at about the time when the tubers are ordinarily half to two-thirds grown. When a plant once shows the infection to any marked degree, all further growth ceases. The plants seem to stand still and eventually wilt down entirely or else struggle along in a dwarfed and sickly condition for some time.

"A common source of infection in newly planted fields is through the use of tubers for seed that already contain the fungus. Another

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common source of the trouble is from planting the potato in fields that have previously shown the disease within two or three years. Such soils are said to be 'sick.'

"A second period of destruction due to this disease comes during storage. Tubers infected in the field when stored under conditions of

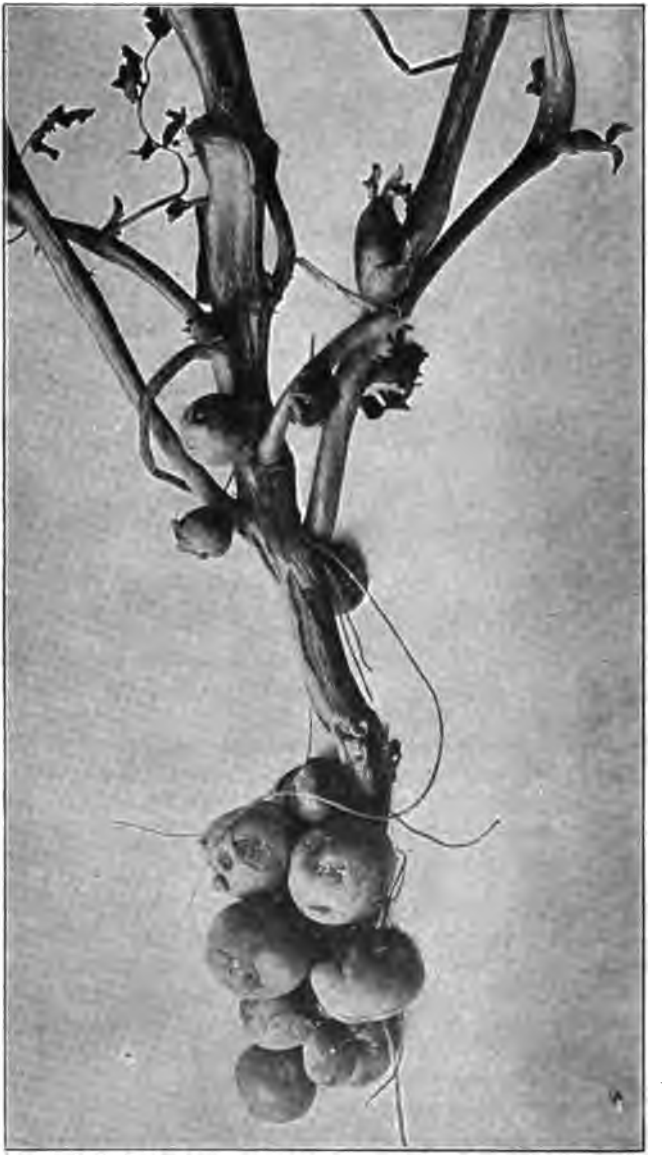

Plate XIII. "Little potatoes" and "aerial tubers," the former in a cluster beneath the soil surface, the latter on the stems above ground.

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moderate temperature are apt to show a high percentage of dry rot. In such cases the fungus causes a blackening of the tuber, with a final outbreak of a whitish mold, and may serve to infect the wounds in other tubers."

Control.—(1) Spraying is entirely useless. The fungus is internal.

(2) Plant clean seed in a clean soil. The fungus is carried in the tubers and lives over in the soil.

(3) Practice crop rotation. This is the important lesson learned by Colorado potato growers. Fields in which *Fusarium* wilt has been bad, should not be planted to potatoes again until a lapse of 5 or 6 years.

RHIZOCTONIA.—This well-known potato disease in Colorado goes by a number of common names: Rosette, little potatoes, aerial potatoes, scurf, stem rot, collar rot, and black ring. The fungus causing the trouble lives in the soil. The symptoms produced by its attacks upon the plant vary. Apparently healthy plants may produce but a few tubers; the plant "goes to top." Again there may be an abundance of tubers, crowded just below the ground surface, but these are small, hence the name, "little potatoes" (Plate XIII). The fungus girdles the stem (Plate XIV), shutting off the movement of starch from leaves to tubers; as a result, small tubers may be formed on stems above ground (Plate XIII). In some instances there is a profuse branching of the plant, and a clustering of leaves at branch tips, which give the plant a bushy appearance. Again the leaves may be twisted and curled. Examination of diseased stems, taken just below the ground line, shows characteristic brown or black surface spots and patches of various shapes. Diseased tubers may be somewhat scabby. Close examination of such will often show the presence of very small black specks, resembling dirt. These black bodies represent a stage of the fungus which lives over winter (Plate XV).

Control.—(1) Use clean seed in a clean soil.

(2) Treat seed before planting with corrosive sublimate. Soak 1½ hours in solution, using 4 oz. of sublimate to 30 gallons of water. Keep solution in wooden barrel—it corrodes metal. Do not eat treated potatoes.

(3) Keep diseased plants and tubers out of stable manure.

(4) Practice crop rotation.

(5) The disease is less prevalent in light, well-drained soil, than in heavy, soggy soil.

INTERNAL BROWN SPOT.—In Colorado this disease affects the Early Ohio almost exclusively. It has not been found on potatoes grown in irrigated sections. It is recognized by the dry, brown

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spots, irregularly scattered throughout the flesh. It is thought to be due neither to a fungus or bacterium. The cause is not known. It is not contagious. Control measures are not known.

Plate XIV. Young potato stems attacked by *Rhizoctonia*. Note the darkened diseased patches near the ground line.

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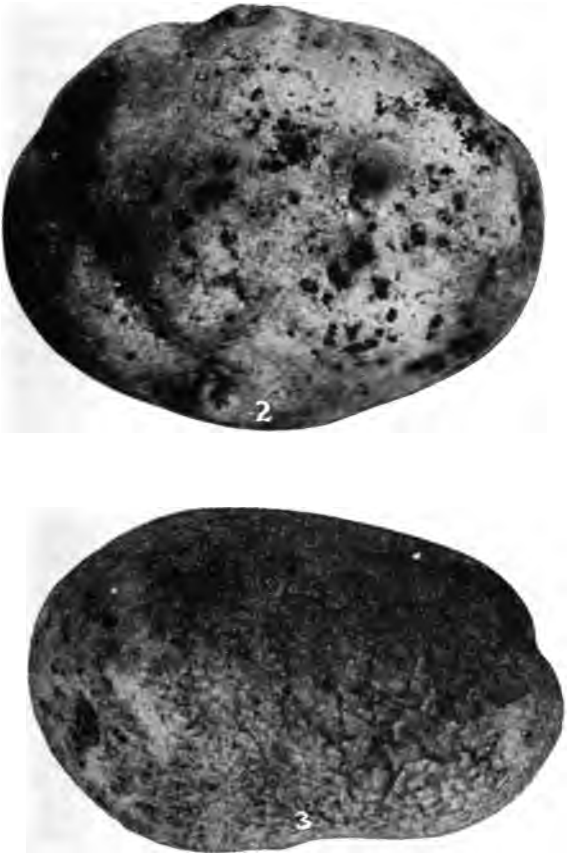

Plate XV. Fig. 2. Sclerotia of *Rhizoctonia* on seed potato. Fig. 3. The fine cracks seen on surface of potato are caused by the attacks of *Rhizoctonia*.

RADISH

WHITE RUST.—The white "rust" occurs not only on radish, but on other members of the mustard family, such as horseradish, turnip, and cabbage. It commonly affects leaves, but is also found on flower parts, distorting them to a marked degree. On the leaves the spore cushions are white and shining, and vary in size from mere specks to irregular patches an inch or more in diameter.

No serious injury has resulted from the attacks of this disease, as far as reports indicate.

RASPBERRY.

ANTHRACNOSE.—Young canes are chiefly attacked, although the disease may also appear on leaf and leaf-stalk. The spots on the canes are at first small and purplish, later they develop gray,

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sunken centers bordered with purple. These spots enlarge, run together, forming irregular blotches which may encircle the canes. Badly diseased canes have roughened bark with a scabby appearance. In severe cases, the canes crack, wither, and die. Affected canes produce dwarfed leaves and premature, undersized fruit, which often dries. The first indication of the disease on the leaf-stalks is the production of minute spots. The fungus spreads from these spots into the leaf, where small affected areas are produced on the under surface. These diseased spots may drop out, causing shot-holing.

Control.—(1) Prune out and destroy all diseased canes.

(2) Rotation of crops. Avoid planting on site of diseased plantation.

Plate XVI. Spur blight of red raspberries. The twig on the right was sprayed.

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(3) Set out only healthy plants.

(4) In severe cases spray young canes with Bordeaux mixture, 4-5-50 formula, with 2 pounds of resin-fish-oil soap added to act as a sticker.

(a) First application, when canes are uncovered.

(b) Second application, when new canes are 8 to 10 inches high.

(c) Later applications, one or two more sprayings thereafter at intervals of 10 to 14 years.

SPUR BLIGHT.—This disease (Plate XVI) is found on the young canes and leaf-stalks. On the lower half of young green canes chocolate-brown discolorations are produced chiefly at the leaf attachments. Later this discoloration spreads, causing some buds to dry, shrivel and die. Other buds are so weakened that the newly developed spurs die soon after starting. No fruit is developed on the lower half of diseased canes. In later stages the disease spreads and discolors the whole lower third of the cane a purple-brown. In this stage the bark often cracks, causing drying of canes. Such stems are brittle and easily broken. Infection on leaf-stalk at first is in the form of a small chocolate-brown spot. The fungus spreads from this spot into the cane. Infected leaf-stalks are weakened and later collapse, causing the leaf to droop and dry up.

Control.—(1) Spray with Bordeaux mixture, 3-2-50 formula, with 2 pounds of resin-fish-oil soap added to act as a sticker. This mixture should only be applied to the young canes and not to the fruiting canes.

(a) First application, last part of May or early June when canes are 8 to 12 inches high.

(b) Second application, two weeks later. Regulate somewhat according to the ripening period of the fruit so as not to discolor fruit.

(c) Third application, two weeks after the second.

(2) Remove and burn old fruiting canes as soon as the berries have been gathered.

ORANGE RUST.—This is a common disease attacking the leaves and canes. The under surface of infected leaves becomes covered with a mass of orange-red spores. The growth of leaves is retarded, and they become curled and distorted. Affected canes are weakened and stunted. They are non-productive and finally die. The fungus lives in the plant from year to year.

Control.—Pull up and burn all diseased plants.

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STRAWBERRY.

LEAF SPOT OR LEAF BLIGHT.—Although this disease is of frequent occurrence in strawberry beds, it rarely becomes serious. It attacks the leaves principally and may be recognized by the characteristic white spots bordered by red or purple. At first the spots are purplish. The degree of susceptibility of a variety toward the disease varies with the locality.

Control.—(1) Remove and destroy all diseased leaves when setting new plants.

(2) The fungus winters over on the leaves. Hence, after the picking season, mow the bed and burn it over.

(3) Although seldom necessary, it will pay to spray in bad cases. Use Bordeaux mixture. Spray 2 or 3 times early in the season, and, if necessary, once later.

(4) Resistant varieties for a locality may usually be found.

BLACK ROOT.—Many plants have been sent to the Station affected with a disease, which we have called "black root." There is a blackening and dying of the roots. As a rule, two-year-old plants are the worst affected, and the disease usually becomes evident in the spring. In a few cases, the trouble has appeared at the beginning of the winter season. No causal organism has as yet been associated with the disease. It seems to be most prevalent on soil that is poorly drained, or in bad physical condition, or on land that has been continuously cropped with strawberries without proper rotation with some legume. However, it has been noted in soil apparently in good condition.

TOMATO.

FUNGOUS (*Fusarium*) BLIGHT.—In this disease the first indication is a yellowing of the lower leaves, followed by their wilting and dying. The trouble may progress slowly, or within a week the entire plant may be dead, depending upon weather conditions and the severity of the attack. In a section of a diseased stem, the woody portion is blackened. Very often the fruit remains attached to the plant and ripens earlier than usual. This is probably the same fungus that is responsible for a part, at least, of wilt in potatoes.

Control.—(1) Spraying is useless.

(2) Remove and burn infected plants. A single diseased plant may be the source of infection of a large crop.

(3) The disease may live in the soil from year to year. Practice a crop rotation system in which tomatoes and potatoes do not come oftener than once in four years.

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(4) Spores of the fungus may be carried from field to field and even from farm to farm by soil or mud sticking to cultivating implements, horses' feet, or workmen's shoes.

FRUIT ROT—BLOSSOM END ROT.—This disease usually appears on half-grown to full-grown tomatoes. It starts in at the blossom end as a slightly sunken, dry spot, which enlarges, darkens, and becomes rotted. The blossom end rot of tomato is considered to be a non-infectious disease.

Control.—(1) The application of fungicides is not effective.

(2) The appearance and progress of disease are favored by dry soil conditions. Keep an abundant and regular supply of moisture in the soil.

SOME INJURIES NOT DUE TO FUNGI

SUN SCALD.—Sun scalding may be developed on the fruit or body of the tree, usually the latter. Cankers are produced on the body. The southwest side of the tree is most frequently injured. Young trees may be killed outright or much weakened. The sun's rays may injure the trees either directly or by reflection from the hot dry soil, or water in irrigation ditches that are placed near the tree. Cankers produced in this manner may easily be mistaken for fungous troubles.

Control.—(1) Newly planted trees should be headed low.

(2) Protect trunks of newly planted trees.

(a) By wrapping the trunks with burlap, paper, straw, wood veneer or wire netting.

(b) By shading the trunk with a board placed on the southwest side.

FROST INJURY (Plate XVII).—Late spring frosts often injure the developing fruit and leaves. Frosted fruits become russeted either at the blossom or stem end, or very often in bands about the middle. Injured fruits may be deformed. "Frost blisters" may be produced on the leaves. Such leaves are crinkled, or have blisters produced by a separation of upper and lower surfaces. The lower surface of injured leaves usually has numerous cracks. Cankers may be produced on the southwest exposure of the tree, due to a freezing of sap and consequent killing of tissue. Such cankers may be mistaken for fungous troubles.

SPRAY INJURY.—Both foliage and fruit may be affected. Injured fruits may be russeted or spotted. Leaf injury may be in the form of irregular, scattered, light brown spots, or the margin of the leaf may be browned, or in severe cases the entire leaf may be

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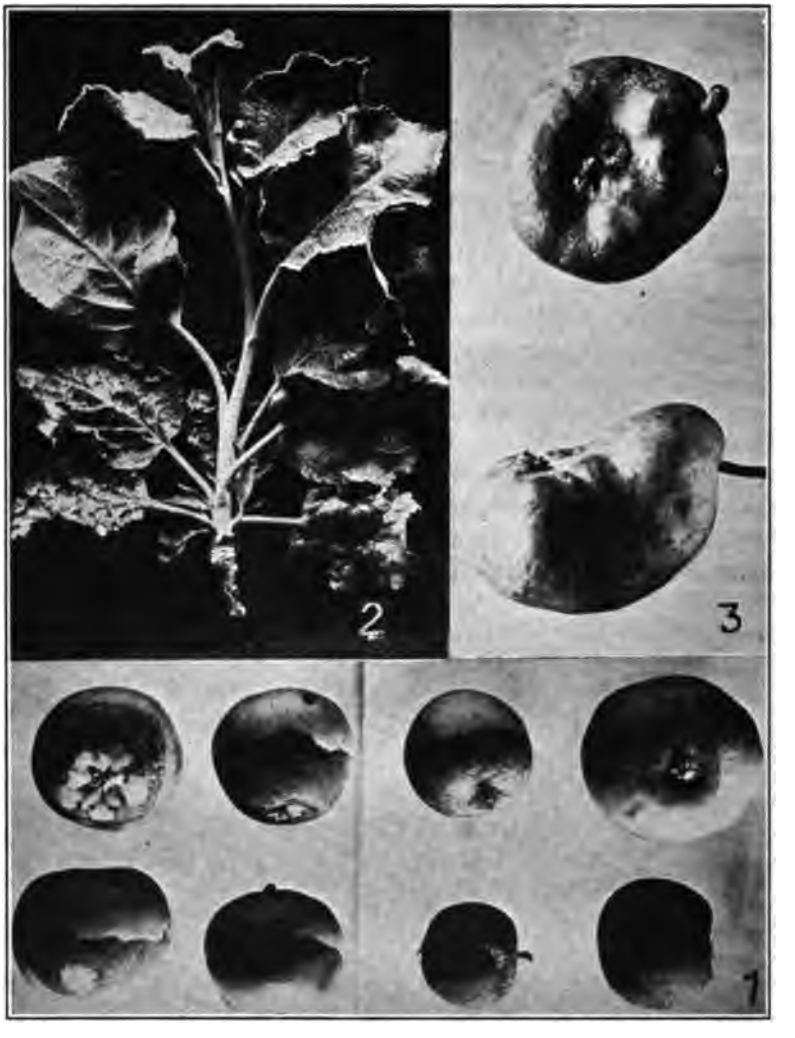

Plate XVII. Fig. 1. Frost injury on apples. Fig. 2. Leaves blistered by frost. Fig. 3. Pears deformed as a result of frost injury.

affected, turn yellow, and fall. In some instances the affected surface may slough off. The effect produced may sometimes resemble shot-hole of plum and cherry.

Control.—(1) Use pure chemicals.

(2) Apply spray as a fine mist, using high pressure and good nozzles.

(3) Apply spray in clear weather.

(4) Stir solution well before application.

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(5) Follow carefully directions for making spray mixture. Do not get it too strong.

"NITER" INJURY (Plate XVIII.—The leaves of fruit trees af-

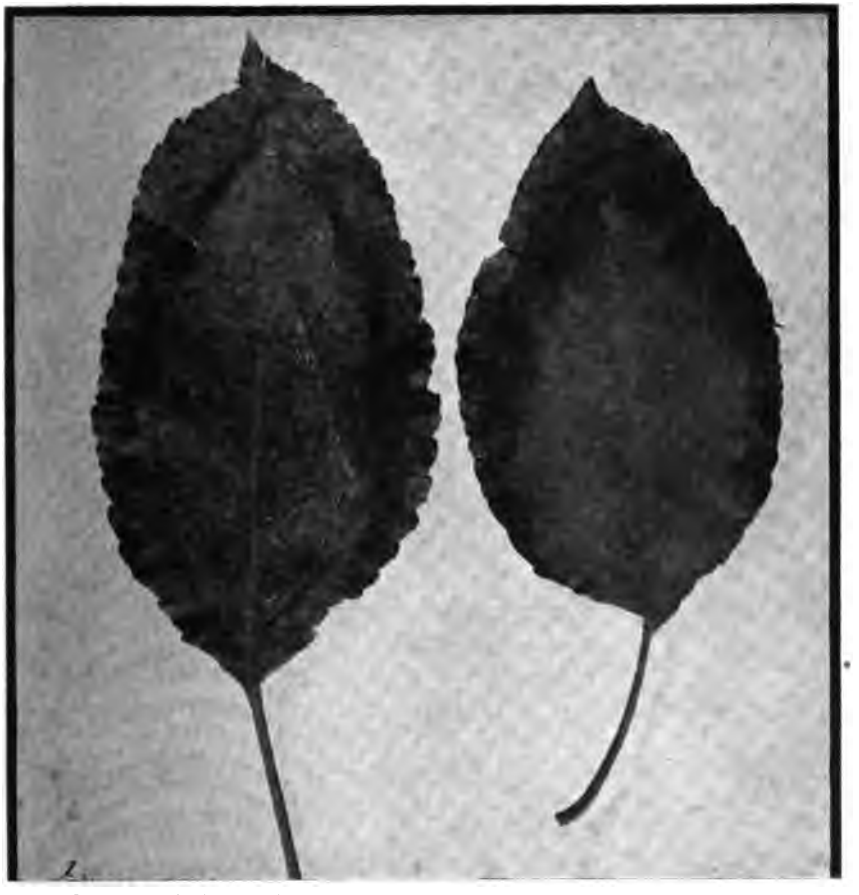

Plate XVIII. Apple leaf with "niter" injury. Note the characteristic browning along the margins.

fected by excessive quantities of niter in the soil have a characteristic appearance. The burning and shrivelling of the leaf begins at the tip, progresses rapidly along the margin, and finally involves the entire leaf. A few limbs, or the whole tree may be attacked. Of all our fruit trees, the apple seems to suffer the most.

ARSENICAL POISONING.—Headden ("Arsenical Poisoning of Fruit Trees," Bulletin 131 (1908) and Bulletin 157 (1910), Colo. Agri. Exp. Sta.), showed that many cases of death of orchard trees in Colorado were due to the action of the arsenic applied to trees

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as a spray. A part of the arsenical spray, especially when used in excessive amounts, eventually reaches the base of the tree, and brings about injury to the crown of the tree.

Headden says, "This trouble begins, in by far the greater number of cases, at the crown of the tree and subsequently involves both trunk and roots. The first marked symptom is an early ripening of the foliage, usually followed by death about midsummer of the ensuing year. The crown of the tree is found to be girdled, the bark on portions of the trunk dead and sunken, and most of the roots dead, their bark destroyed and the woody tissue discolored, usually a light shade of brown, and sometimes exteriorly blackened."

Arsenical sprays constitute our most valuable insecticides and their use is not to be discouraged. But they should not be applied in excessive amounts. There is a tendency with some to give more applications than necessary.

"SEEPAGE."—Trees dying from too much water show symptoms markedly different from those affected with "niter." All the leaves of the tree may turn yellow. Discoloration of the leaf does not progress from the tip along the margins, as in "niter" leaves, but the leaf seems to be affected as a whole. Affected portions of "niter" leaves are brownish in color from the first, never yellowish. Trees killed by too much water never show girdling at the crown as do those killed by arsenic.

PREPARATION OF SPRAY MIXTURES AND DISINFECTANTS.

BORDEAUX MIXTURE.

Materials Used—

Copper sulfate (blue vitriol)	4 lbs.
Stone lime	5 lbs.
Water	50 gals.

This makes a 4-5-50 mixture of the spray. The amount of copper sulfate can be varied according to the formula given. The weight of stone lime should be equal to or exceed the weight of copper sulfate.

Apparatus—

2 half barrels with a capacity of about 30 gallons, made by sawing in two a 60-gallon barrel.
1 60-gallon mixing barrel.
2 or more wooden pails.
1 strong paddle, about 7 feet long.
1 pair hand scales.
1 strainer, of cloth or 20-mesh brass gauze.

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Preparation—

4-5-50 *Formula From Fresh Material.*

1. Dissolve 4 pounds copper sulfate in hot water, place in half barrel and add water to make 25 gallons.

2. Slake 5 pounds of stone lime in the second half barrel and add water to make 25 gallons.

3. Mix solutions by having two operators, each provided with a bucket, dip up equal amounts of the copper sulfate and lime solutions, respectively, and pour them together at the same rate at a height of two or three feet above a mixing barrel (Plate XIX).

Plate XIX. Showing method of mixing copper sulfate and lime solutions in preparation of Bordeaux spray mixture.

4. Mix the whole thoroughly by stirring vigorously.

5. Strain the mixture when putting into the spray tank.

6. Apply to the plants with any good pressure spray pump. Use as soon as made.

If other than a 4-5-50 formula is given, take respective pounds as indicated in formula. For example, to make a 3-2-50 formula, take 3 pounds of copper sulfate and dissolve in 22 gallons of water, and 2 pounds of lime and slake and add to 23 gallons of water. Mix the two as before indicated.

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Stock Solution.

Where spraying is to be done on a large scale, "stock solutions" of copper sulfate and lime are made up in advance.

1. Place 50 pounds of copper sulfate in a clean gunny sack and suspend it just beneath the surface in a barrel containing 50 gallons of water. This dissolves in 12 to 24 hours. One gallon of the solution contains 1 pound of copper sulfate.

2. Slake 50 pounds of good quality stone lime in a barrel and add water to make 50 gallons. When stirred, 1 gallon contains 1 pound of lime.

Preparation of 4-5-50 Formula From Stock Solutions.

1. Stir stock solution thoroughly.

2. Put 4 gallons of stock solution of copper sulfate in one of the half barrels and add water to make 25 gallons.

3. Put 5 gallons of stock solution of lime in the other half barrel, and add water to make 25 gallons.

4. Mix, following directions as given in preparation of 4-5-50 formula from fresh solutions, under 3, 4, 5, and 6.

5. After removing enough of the stock solutions for one spraying, mark on the barrels by nailing strips of boards just at the top of the solutions. Before the next spraying, add water to bring the solution up to these marks. This replaces the water lost by evaporation and gives a solution of known strength.

If other than a 4-5-50 formula is given, take respective gallons as indicated in formula. For example, to make a 3-2-50 formula, take 3 gallons of stock solution of copper sulfate and put into 22 gallons of water, and 2 gallons of stock solution of lime and put into 23 gallons of water. Mix the two as before indicated.

Preparation of Bordeaux Mixture With Addition of Resin-Fish-Oil Soap.

1. Dissolve 2 pounds of resin-fish-oil soap in 2 gallons of water.

2. Add only enough water to the slaked lime, before mixing, to make 23 gallons.

3. After the copper sulfate and lime solutions have been mixed, add the 2 gallons of soap solution.

4. Mix, strain, and spray as before indicated.

COMMERCIAL LIME-SULFUR SPRAY.

Buy the commercial product from some reliable dealer and use as directed.

SELF-BOILED LIME-SULFUR SPRAY 8-8-50 FORMULA.

Materials—

Stone lime	**32 lbs.**
Flowers of sulfur	**32 lbs.**
Water to make	**200 gals.**

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In this preparation 4 times the 8-8-50 formula is used because it has been found that these quantities give more satisfaction and convenient conditions for cooking than when smaller or greater amounts are used.

Apparatus—

1 strong 50-gallon barrel.
1 strong paddle, about 7 feet long.
1 sifter (flour sifter).
2 or more buckets.
1 pair hand scales.
1 strainer, of cloth or 20-mesh brass gauze.

Preparation—

1. Weigh out 32 pounds each of lime and sulfur, having first sifted the sulfur.
2. Place lime in barrel and add about 4 gallons of water.
3. Add sulfur as soon as the lime begins to slake vigorously.
4. Stir preparation vigorously with the paddle, adding enough water from time to time to avoid "burning," and still not enough to "drown" the lime.
5. Add at least 25 gallons of cold water with vigorous stirring as soon as the lumps of lime are thoroughly slaked. It is very necessary to cool the preparation at this time by adding the water as indicated.
6. Make up to 200 gallons, or dilute fractions of the stock solution correspondingly.
7. Strain before putting into spray tank by running the solution through a cloth strainer or a 20-mesh brass wire strainer. Work through any lumps of sulfur with a small paddle.
8. Apply the spray with any good pressure spray pump.

AMMONIACAL COPPER CARBONATE.

Copper carbonate	**5 oz.**
Ammonia	**3 pints**
Water	**45 gals.**

Preparation—

1. Add water to the carbonate to make a thin paste.
2. Dissolve the carbonate in ammonia, diluted with about 2 gallons of water.
3. Make up to 45 gallons.

FORMALIN.

Non-poisonous to animals.

Formaldehyde (40%), also called Formalin	**1 pint**
Water	**40 gals.**

The above is the usual formula for formalin. The amount of water used varies with the use to which solution is put and with length of treatment. Use as directed in special cases.

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CORROSIVE SUBLIMATE.

Deadly poisonous to animals.

Corrosive sublimate crystals	**4 oz.**
Water	**30 gals.**

Dissolve the corrosive sublimate in 2 or 4 quarts of hot water, and dilute this strong solution with water to make 30 gallons.

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OF THE

Colorado Agricultural College

POULTRY RAISING IN COLORADO

—BY—

W. E. VAPLON

Under Ground Poultry House

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1915

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FORT COLLINS, COLORADO

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FORAGE CROPS FOR THE COLORADO PLAINS

By Alvin Kezer

INTRODUCTION

It is the purpose of this publication to treat of some of the fundamental considerations necessary for the growing of forage crops on the Colorado Plains outside of the irrigated districts. The farming conditions are those commonly called "dry farming." Considerable experimental work has been done from time to time at Cheyenne Wells, Monument, by the Government at Eads and Akron, at Julesburg, and cooperatively at a number of other points. The experimental work has been supplemented by the work of different field agents from time to time, and several years acquaintance and observation thru this territory.

CLIMATE AND TOPOGRAPHY

The Colorado Plains constitute a part of what is known as the Great Plains area. They lie east of the Rocky Mountains and extend from the base of the foothills to the state line. These plains are, for the most part, smooth to rolling prairies. Thru the northern part, the Platte River has cut its valley, which gives rise to an extended depression extending north-easterly from the city of Denver to the state line. Thru the southern part, running almost due east and west, the Arkansas River has cut its valley, creating a depression and many soil modifications due to stream flow and the deposition of soil material from flowing water. The Divide region between the Platte and Arkansas drainage reaches a considerable altitude, above 9,000 feet. This divide decreases in altitude and sharpness of slope towards the east, being much flatter as it approaches the eastern border. The streams cause more or less breaks and some rugged features in the otherwise general smooth to rolling appearance.

The climate is mild-temperate, but subject to very sharp extremes of both heat and cold, moisture and dryness.

The normal rainfall as shown by the Government and State rainfall records, varies from a minimum of approximately 8 inches to a maximum of about 18 inches. In years of drouth the rainfall is very much less than normal, while in years of heavy precipitation—so-called wet years—rainfall greatly exceeds the normal.

The region is one vast, unprotected, treeless plain, and as a consequence it is subject, especially during the spring and fall months,

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to violent winds. A considerable knowledge of the climatic features to be met is essential because it has a strong bearing upon the cropping possibilities of the region.

The altitude of this region is high, varying from a minimum of about 3,500 feet to over 10,000 feet. These altitudes are associated with short seasons and cool nights.

SOILS

For the most part, the soils are exceedingly rich and deep. There are, however, localities in which the surface soils are underlaid close to the surface with the country rock. This country rock is quite variable in its exposure—different geological formations are exposed in different localities. For the most part the soils are rather light in nature, running from sandy loams to as coarse as gravelly loams, sandy and silt loams predominating. There are an extremely small number of places where heavy clay and adobes prevail. The acreage, compared to the 22,000,000 acres of plains lying in Colorado is relatively small.

In the eastern and northeastern portion there are some areas of almost pure sands. These have been blown about by the winds to form sand dunes or sand hills. Sand dunes appear at other points in the Colorado Plains, but in less extensive areas.

In some sections the soils are almost pure silt, making loams of great depth, more available water relations, and amount of rainfall considered, unusual certainty of productivity.

The U. S. Bureau of Soils has made surveys of soil types in Larimer and Weld counties, and in the Arkansas Valley. These surveys and a careful checking of the same territory by later workers, show that the prevailing types in those different sections are largely sandy loams and silt loams. Those soils which have the proper physical texture and great depth are the ones which are capable of supporting a dry farming population. No matter how favorable the texture may be, if the surface soil is underlaid at a short depth with impervious clay layers, or with one or another of various beds of country rock, or with gravel, it is unfit for dry farming purposes except in the very wettest years, because such shallow soil is not capable of supporting vegetative growth thru prolonged periods of drouth.

In the sand hill regions the tendency to blow in the prevailing high spring and fall winds is so great that except in wet valleys, the soil should not be broken up. An effort should be made to make use of the native pastures and to increase their carrying capacity by intelligent grazing methods, by seeding in such crops as Sweet Clover which seems to thrive under such conditions. Even the sandy loams and silt loams if plowed up so as to dry out, and if finely pulverized at the surface, will blow in a very short time after being broken up—that is, as soon as the organic matter contained in the fresh sod is reduced in amount. It is essential, therefor, on all lands to carry on some system of farming which will assist in keeping up the organic matter content; to resort to such a system of plowing and cultivation as will leave the immediate surface more or less rough and quite coarsely granulated.

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If the surface is granulated from the size of small gravel up to the size of a walnut, there is almost no danger of its blowing. A finely pulverized surface will almost certainly blow, no matter what the texture of the soil.

On all but the very sandiest lands, soil blowing may be controlled. Control methods consist of keeping the immediate soil surface rough on all plowed land and cultivated land not in crop. Anything which will break the force of the wind at the soil surface is effective. On many soils where the tendency is to blow badly, fall plowing can not be done. Usually, however, such lands may be fall listed crosswise of the direction of the prevailing winds. The furrows furnish sufficient protection to largely prevent blowing.

When a crop is to be planted, other protection is sometimes necessary. One successful method is to plant grain in strips alternate with listed land. Corn or some of the sorghums are planted in the listed furrows. Having these strips at least a rod wide and placed from ten to forty rods apart furnishes protection against soil blowing on any soils except the purest sands.

DRY FARMING

The commonly accepted definition of dry farming is taken to be the production of crops without irrigation in a region where the rainfall is between 10 to 20 inches per annum. Much work has been done in an attempt to find adapted crops for dry farming; to find out the principles of water movement; the principles of moisture conservation; and what practical methods of plowing and cultivation must be followed to get the best results. At first, both practically and scientifically, the effort seemed to run itself to the production of grain crops or a knowledge of the principles underlying their production. Long experience, however, has shown, and a study of the climatic and moisture conditions of the soil bears the opinion out, that any system of farming which depends upon the production of cash grain crops on dry lands of the Colorado Plains, is destined to failure in all but a very few localities.

The crops which grow and thrive best, which are most certain of reaching harvestable maturity, are forage crops. Owing to their bulk and to the varied character of these crops they can not generally be marketed directly for cash. They must therefor, be fed to some kind of livestock and the livestock marketed if a permanent system of agriculture is to be established and maintained in this region. With the proper use of forage crops and livestock, with perhaps the growth of small acreages of the best adapted cash crops, and the use of livestock, a permanent system can be established. The cash grain crops will not bring in money each year, but occasionally they will make an agreeable addition to the money supply of the family. The main dependence, however, must be placed upon forage crops marketed thru livestock.

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GENERAL FARM PRACTICE AND MANAGEMENT

Dry farming at its best is serious business. As a consequence, there are certain fundamental considerations which the settler should bear in mind. A well for domestic water supply is absolutely essential. If such domestic water supply can not be obtained upon the land or immediately adjacent to it, other features would have to be extremely desirable to make it advisable to locate a home. The production of crops is more or less uncertain and the prospective settler should by all means bring sufficient capital in money, or in money and materials, to carry him thru at least one year until production can be started.

For the most part the plains are treeless. In the building of a home, one of the first things, after the house and sheds for livestock are provided, should be the making of some provisions for trees. Where land is properly prepared and properly cultivated, trees can be grown almost anywhere on the plains, providing they are given sufficient space. The moisture supply on dry land soils is always less abundant than it is in the humid regions; consequently the trees should be set much farther apart. The sod should be broken up at once in preparation for planting trees. A strip should be plowed at least twenty feet wider than the expected space which the trees will occupy. This should be kept free of weeds by plowing or other form of cultivation to permit the accumulation of water. Sometimes the soil can be sufficiently moistened, when such clean cultivation is followed, in one season to permit perfect safety in tree planting. Sometimes two seasons must elapse, and in extreme seasons as many as three. The ground should be ready and have sufficient moisture before trees are put out.

The planting of trees will make it possible to have some shade about the home. In addition to this, trees will break the dreary monotony of the plains—a monotony which is very real to all those not born and bred plainsmen. The women folks of the family are especially susceptible to this loneliness because of the isolation and difficulty of social relations with the neighbors.

The dry farmer should make provision for a garden somewhere near his well. If a good well is present for domestic water supply it can be used, especially if a little storage is possible, to insure a good small garden if the water is properly applied at the right time.

The dry farmer should by all means plan his cropping system so as to grow feed for at least a few chickens and pigs, so that the family living will be insured. The type of other livestock which he chooses to grow will depend a good deal upon his location, as either dairy or meat animals can be made profitable. There will be seasons when an abundance of feed will be produced. There will be other seasons when the amount of feed produced must be very carefully husbanded in order to permit existence; consequently, sooner or later the dry farmer should come to the proposition of saving all of his feed, and in extra

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good crop years to store up excess feed to tide him over the lean years which are bound to follow one season or another.

The wide use of the silo is bound to come as a part of this development, because it permits all, or practically all, the feed grown to be stored in available succulent condition for future feeding. In 1912 the Experimental Sub-Station at Cheyenne Wells produced feed enough to have carried the herd on the land at that time for a period of two years. The silo capacity was limited to two pit silos at that time. They were filled to capacity, but they were only capable of carrying the herd thru the winter and the following early summer. In 1913 by saving every bit of feed that it was possible to save and putting it into the silo, it was not possible to quite fill even these two silos. In 1914 two more silos were put down so that now we have capacity enough to carry the normal regular herd thru a period of two years if extreme conditions should appear.

No method of dry curing of the crop is so efficient that it does not waste at least as much as thirty per cent. In the dry windy conditions which prevail as much as eighty per cent of the feed value may be lost. If put in the silo at least ninety per cent should be saved under normal conditions. In other words the loss need not be over ten per cent and often will be less than five per cent. The silo making possible this great saving in feed is bound to have a much greater use upon the dry farms.

In many places dry farmers are making use of open range available to carry their stock in the summer. During some seasons this open range will be cut short by extreme drouth so that the animals lose flesh or fall off in milk production according to the kind of animals kept. If the dry farmer had a silo at this time he could open the silo and feed some silage during the period of short pasture and keep up his gains on beef animals and his milk production on dairy animals.

The entire system can be summarized then, briefly as follows: Forage crops are best adapted to the soil and climatic conditions. In the best management they should be grown and placed in the silo to be fed later to livestock. Grain farming should be entirely supplementary to the general system. Of the grain cash crops which may be grown, we have winter wheat, flax and Mexican beans. With winter wheat and flax especially, the farmer should look upon the proposition as a chance for getting something extra, his living and his main returns to be obtained from livestock which are fed upon forage crops.

ALFALFA

Farmers, experimenters and others have long recognized the need of a reliable legume crop that would supply forage for the dry farming sections of the plains. Alfalfa was tried and pronounced a failure by most of the persons who tried it. The fault was not entirely that of the alfalfa. In attempting to produce alfalfa, planting was done in

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exactly the same way, using the same amount of seed as was used in irrigated and more humid regions. Frequently also, improper and unadapted varieties were used.

In the dry farming sections of the plains the water supply is always limited, except in an occasionally unusually wet year, and thick planting of alfalfa, such as thrives under irrigation or in humid conditions did not survive because there were more plants upon the land than there was soil water upon which they could draw. Failure, of course, followed.

In a practical way the Brott Brothers of Sextrop, Nebraska, just across the northeastern Colorado line, were the first to successfully solve the difficulties. Their method of meeting the difficulty was to plant alfalfa in rows and cultivate. Different distances to plant the rows were experimented with until finally it was decided that under dry land conditions it was necessary to put the rows from 3 to 3½ feet apart.

J. E. Payne, working as Agronomy Field Agent of the Experiment Station, worked out six or eight years ago the fact that alfalfa must be planted thinly on the land if it is to survive in the dry land sections. Under his direction a number of farmers made broadcast plantings using 3 and 5 pounds of seed to the acre. The three pound seedings were the most successful. Definite experimental work since that time has shown for Colorado conditions that it was necessary to plant alfalfa in rows in order that the number of plants might be easily limited on the land to prevent other plants coming in and competing for a part of the moisture supply, and the rows cultivated to keep down weeds.

In the past four years, successful row plantings on dry lands have been made in Weld, Larimer, Sedgwick, Elbert, El Paso, Lincoln, Cheyenne, Kit Carson, Otero, Crowley Counties and a few other localities. Experience with these plantings has been that row planting is a success for seed production. When it is considered that on an average the grower can count on a yield of about three-fourths of a ton of cured hay per annum for dry land conditions, it must be acknowledged that row planted alfalfa gives promise of having a very important place among the forage crops of the dry lands.

Varieties.—Experimental work has shown that the less hardy common alfalfas are absolutely no good for the dry lands. Work of the Experiment Station has shown that Baltic, Grimm and Hardy Turkestan alfalfa are the best varieties, in the order named. The Baltic and the Grimm are very much alike—in fact, the Baltic is a selection from the Grimm. These two sorts are very superior, both for hay and seed production wherever we have experimented with them on the Colorado Plains. Next to these varieties just mentioned, it has been found that if common alfalfa is used, the seed of which is taken from fields which have stood eight or ten years, that fairly good results are always obtained. Where the field of alfalfa has stood for ten years, most of the weak and non-hardy plants have been killed out so that seed is obtained only from plants capable of enduring the con-

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ditions. When selected in this way seed may be taken from irrigated regions.

Preparation of the Seed Bed.—Alfalfa is a crop that is going to occupy the land for some years, so every possible precaution must be taken to get it started with the desired stand. In order to do this the seed bed must be prepared. It is necessary to get moisture into the seed bed before it is safe to put in the seed. There should be moisture enough to carry the crop for some months without additional rainfall. To accomplish this purpose the soil should be moist to a depth of at least two feet before plantings are made. Of course it is understood that rains are always liable to come and wet up the soil. It is also well known that rains may fail to come for periods of three months. In order to be on the safe side, alfalfa should be planted only in soil that is properly prepared, with the right amount of moisture to start the seed off and keep the crop growing for a period of at least two or three months without help of rainfall. In preparing such a seed bed it is frequently necessary to adopt the summer fallow. The land should be plowed thoroly and deeply. It is well to disk the soil immediately after the plowing in order to flatten the furrow slice.

Alfalfa does best on land which has been plowed and then afterwards well packed. The surface should be left granular rather than fine and dusty. The granular or "small cloddy" surface not only takes up the moisture which falls better than a dust surface but it protects the moisture supply present much better and is in very much less danger of blowing. When the seed bed has been properly prepared and has a sufficient supply of moisture present, the soil is ready for planting.

In most of our plains districts the rainfall is such that the best moisture conditions prevail between March and the first of July. On a properly prepared seed bed seeding may be done with safety any time from early in April until the first of July—preferably April and May seeding if the seed bed is in condition, because the alfalfa will grow better if it has a root system started before hot weather of July and August, and planting should be done in rows 3 to 3½ feet apart.

Where the prevailing winds are north and south the rows should be planted east and west. In other words, wherever the lay of the land will permit, the rows should be crosswise of the direction of the prevailing winds.

Seed should be put in with some sort of a drill. It is possible to rig a corn planter by using extra seed cups from some of the grass seeder attachments with which many of the modern drills are equipped.

With Baltic and Grimm seed, if the soil is properly prepared, one-half pound per acre, with rows 3½ feet apart is sufficient. With most methods available probably about two pounds will be planted, because of the difficulty of regulating the drop so as to drop less. Careful, patient, mechanical farmers can devise ways of reducing the rate of

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planting. For many of our experimental plantings, Mr. P. K. Blinn devised an attachment which could be put on the corn planter and beet drill, or even attached to a grain drill. We obtained some of the drop cups manufactured for the grass seeder attachments of one of the standard makes of drills. These were provided with individual seed boxes which were mounted upon a drive shaft in such a way that their width was readily adjustable. Then by means of a couple of sprockets, it was possible to drive the drill from the shaft of a corn planter, grain drill, or a beet drill. With this device several hundred acres were successfully planted.* A number of farmers have devised ingenious corn planter attachments for row planting. If the soil has been properly prepared very little cultivation will be needed after seeding until the crop has gained some little size. If it is necessary to cultivate the plants while small, shields should be used on the cultivators. After the plants get above five inches in height, cultivation is easy. The cultivation given should aim to keep down weeds and to prevent the formation of a crust.

Harvesting.—When the row alfalfa is harvested for hay it is cut with a mower and put up in the same manner as any alfalfa. If there is dew present, the mowing should not be done until the dew is off. The hay should be raked before it has had time to do anything more than slightly wilt. Further curing is done in the windrow or cock. It can be done more rapidly than is possible in the swath. If left in the swath the leaves dry up almost at once leaving the stems full of water. If it can be raked into a loose windrow so that the leaves are partially shaded, the evaporation or drying will go on very much more rapidly, because the moisture will pass out thru the leaves more rapidly than it will pass thru the stems.

When harvested for seed it is necessary to determine at what time to cut. The aim should be to cut it at such a time as to get the greatest number of ripe seed pods. Unfortunately the seed pods do not all mature at once. Usually if the cutting can be done when about three-fourths of the seed pods are ripe the greatest amount of seed possible will be obtained. When cut for seed the mower is again the most desirable tool to use. If a buncher attachment is at hand the problem is easy, as a man can walk along behind the mower and move the bunches over so the horses in making the next swath will not walk upon the cut alfalfa. This precaution is rather necessary, especially in dry times, because if the horses walk upon the cut swath they will thrash out and break off a large amount of seed. If a buncher attachment is not at hand it will probably be necessary to either rake or lay over swaths with forks. The ripe swath can be placed in a loose windrow and allowed to cure there, or into small cocks. As soon as the stems are dry enough, it can be thrashed, or if thrashing facilities are not immediately available, it can be stacked in order to keep it in condition until thrashing can be done.

* The drill manufactured by the Columbia Drill and Planter Co., Springfield, Ohio, has a drop which can be successfully attached for seeding alfalfa in rows.

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CORN

Corn is commonly considered a grain crop, yet upon the Colorado Plains it is one of the l ading forage crops, and in many sections will be the leading grain forage crop. In the higher and moister sections, on the Arkansas-Platte Divide region, corn will produce a greater tonnage than any other similar forage. There are many other localities where it will out-yield the grain or forage sorghums. Where corn will out-yield such other crops it should be used for forage. It makes an excellent fodder where properly cured and when stored in the silo makes the very best silage possible. Corn can be grown in cooler localities than can any of the sorghums. It is probable, therefor, that corn will take the first place in the cooler and moister sections, while the sorghums will take first place in the dryer and hotter sections of our territory.

Preparation of the Soil.—The best method of soil preparation for corn depends upon the character of the soil, the rotation, and the crop which precedes corn on the land. If the land is rather light and sandy, fall plowing is not wise on account of danger of soil blowing. However, such lands may usually be managed so as to keep down weeds and put the surface in shape for catching winter and spring moisture. Where small grain or an early harvested cultivated crop preceded corn, the land may be double disked at once to kill weeds and put the surface in good condition for catching rainfall. Then, instead of plowing, the land is listed. Experiment shows that this practice stops danger of blowing. In the spring, just as early as possible, the middles are broken out.

Listing tends to lengthen the time required to develop corn to full maturity, consequently, planting corn on listed land is not always advisable. Where, on account of the difficulty of maturing listed corn, it is advisable to surface plant, the listed ground is worked down by disking and harrowing.

Often on the lighter lands, experiment has shown a system may be followed which keeps down weeds and conserves moisture at a great reduction of labor without reducing yields. Thus the cost of production is kept down. The suggested system is carried out as follows, starting the system and rotation with summer tilled land. The first crop put on is winter wheat. Immediately after the binder, the land is double disked for the double purpose of killing all weeds which spring up and to put the surface in good condition to catch rainfall. The following spring the land is double disked early, then corn or other cultivated crop is planted. Following corn, small grain is planted. The yields of grain after corn or other clean cultivated crop are nearly as large as after the fallow. As this last small grain crop is cut, the land is double disked. It is then allowed to lie. The following spring, as soon as weeds start, the soil is again disked to kill weeds, preserve tilth and the better to catch rainfall. In June and July the land is plowed thoroly and deeply, disked and harrowed immediately behind the plow. Winter wheat is planted in September and the rotation is under way again. Such

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management has been found more successful on many soils than more frequent plowing and the cost of following the system is very low.

Upon the soils which give better results from plowing each season, the soil should preferably be plowed early in the fall, the earlier the better.

Over most of the Plains area, corn can be planted by the 10th of May. In the extreme southeastern part of the Colorado Plains, planting can be done the last of April or the first of May. In the extreme eastern part, some planting may be done by the first of May, but usually it is not wise to put in corn very much before May 10. Nearly always the Plains are subjected to a frost about the middle of May and there is little use of getting corn in prior to this danger period for frosts. By this time, the ground has become somewhat warmed so that the crop will start off readily.

Corn should be planted in rows 3½ feet apart. If drilled on the dry land there should be one seed about every 18 to 22 inches. If check-rowed, only two kernels to the hill should be planted.

In very dry localities where experience shows difficulty of getting sufficient moisture to produce a crop, the rows may be planted 7 feet apart or double the usual distance. When thoroly cultivated, such wide planting insures a crop in years when ordinary planting fails. With such wide planting, the seed may be put in a little thicker, 15 to 18 inches, in the row when drilled. This method of planting has been tried with success in several Colorado Plains localities.

Varieties.—There are an infinite number of corn varieties, but owing to the altitude and the shortness of the season, only the short season or so-called northern corns should be planted. Of the native varieties which have been tried out, the Swadley Dent, the White Australian Flint, and Parson's High Altitude corn have given very excellent results. For the more northern portions of the Colorado Plains area, Pride of the North, Minnesota Nnmber 13, Minnesota Number 23, and Wisconsin Number 7 have been tried and have given good results. Of the imported corns, Minnesota Number 13 and Wisconsin Number 7 have been among the best. Minnesota Number 23 has not been tested a very long period of time, but gives promise.

For dry land forage purposes, it is unwise to plant the large-eared, late maturing types of corn. They are more subject to injury, will not produce as heavy yields and will not mature seed with any certainty.

Cultivation.—The major portion of corn cultivation should be done in the preparation of the seed bed. Cultivation after planting should be relatively shallow and frequent enough to prevent weeds gaining a foothold, and prevent the formation of a crust. For this purpose, the use of a type of cultivator having numerous shovels to the gang should be used. Numerous small shovels work up the entire surface thoroly and do a better job than the larger shovels as ordinarily used. Cultivation should be approximately four inches deep. It is seldom wise to go deeper, as root pruning becomes severe and very injurious, especially in dry times.

Harvesting.—For forage purposes it should be the plan of the dry farmer to put his corn crop largely in the silo. Corn should be allowed

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to mature pretty well, at least to mature until the ears are well dented and glazed before the crop is harvested, as it will make better silage and a greater yield of feed if harvested at this time. It will not be harmful if some of the lower leaves are dry, because water can be run into the silage as the silo is being filled.

If cut for fodder it should be cut at about the same time as for silage and put at once into shocks. As soon as cured it should be taken in from the field and stacked in order to reduce the waste from the dry, high winds of winter to as low a minimum as possible. With the silo, it is possible to save ninety to ninety-five per cent of all of the feed produced in the field. With the best methods of dry fodder making, not over seventy per cent will be saved, and there will be a great deal more waste in feeding as the animals will not eat nearly so much. Often where the crop is harvested by cutting and shocking, weather conditions will be such that as much as eighty per cent may be lost, altogether too high a loss to be permitted where forage is as scarce as it is upon the ordinary Plains farm.

SORGHUMS

Two kinds of sorghums are commonly grown. Both have about an equal resistance to dry weather and drouthy conditions. These are forage, or saccharine sorghums, and grain, or non-saccharine, sorghums. The latter are distinguished from the saccharine sorghums in that the juices are not sweet. They are ordinarily called grain sorghums because they produce heavy yields of seed or grain which is well adapted for feeding purposes. The sorghums have one very valuable characteristic—in drouthy periods they will cease growth and unless the drouthy period is exceedingly prolonged, will recover and continue growth if moisture comes later. The sorghums have a very large place in the forage crops of our dry land regions because of their ability to withstand drouth. They can not be successfully grown in some localities because of the cold climate resulting from the high altitudes. Where the sorghums will out-yield corn, they should be grown for forage purposes in preference to corn.

Forage Sorghums or Sorgos.—The forage sorghums can be grown practically all over the Colorado Plains. In some localities near the foothills and in some localities on the Platte-Arkansas Divide, the altitudes are too high and the climate too cool for the best development of even the shortest-season sorghums.

There are a large number of varieties and types of sorghum. Practically only two types are adapted to any of our regions. These are the Ambers and Sudan Grass. Of the Ambers we have Black Amber, Red Amber, and White Amber. The White Amber was produced by selection by Mr. Freed of western Kansas. It is called in many sections and in some Government literature, "Freed's Sorgo."

Sudan Grass is not commonly called a sorghum, but for the purpose of this bulletin, it can be classed with the sorghums. It crosses

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"Freed's Sorgo" grown at Akron, Colorado

readily with the Ambers or other sorghums, showing its close relationship.

Of the Ambers, the Black is the best variety. Altho in our experimental work at Cheyenne Wells, the White did well, it was not equal to our local strains of Black Amber. The Amber sorghums are best adapted to the southeastern portion of the State although they do well in the extreme eastern portion. They are less well-adapted as the altitudes rise close to the mountains, but even here they may be grown to some extent.

Sudan Grass has been tried in the State for 3 years. It was imported from Khartum in 1909. Sudan is a province in Central Africa, of which Khartum is the leading city. On this account the Department of Agriculture officials called the grass Sudan Grass. This grass has been tested for 3 years in Colorado and has given promise of being the best adapted hay crop of the forage sorghum types. It matures in a shorter season than Amber, stands drouth well, and grows vigorously. Its yield will, of course, be largely according to the moisture supply available and it will vary from 1 to 8 or 9 tons. The latter yield is only possible under irrigated conditions. Sudan

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A single Sudan Grass plant, 7 feet high, showing heavy stooling habit.

Grass is not adapted to the higher altitudes next to the foothills nor in the Platte-Arkansas Divide, but is adapted to the rest of the Colorado Plains.

Preparation of the Soil.—The soil for sorghum should be prepared the same as for corn. Owing to the fact that all of the sorghums are what might be termed hot weather crops they require a warm soil before it is safe to plant. This planting should follow corn planting, usually from the 15th to the 20th of May is a safe time. Planting may even be delayed until early in June.

If seeded broadcast 20 to 30 pounds of Amber will make a thick enough stand. In most of the dry land regions, it will pay however, to plant the sorghums in rows so as to permit of cultivation. Six to 15 pounds per acre in rows, according to width of rows, will be amply sufficient upon most soils. Sudan Grass is smaller seeded and consequently a fewer number of pounds will do. If planted in rows 3 to 6 pounds will make a sufficiently heavy stand. If planted broadcast 10 to 15 pounds is abundantly sufficient.

Not Safe to Pasture.—Owing to the fact that the sorghums develop a poisonous principle which causes the liberation of hydrocyanic acid, commonly called prussic acid, it is unsafe in dry land regions to pasture with livestock. This poisonous principle seemingly

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Sudan grass, 7½ feet high, grown near Rocky Ford, Colorado, on irrigated land, but without irrigation. Seasonal rain fall of 11 inches. Seeded May 15, photographed July 30

does not hold its effectiveness when the crop is cut and made into hay or made into silage. In other words changes occur so that the poison is no longer injurious.

Harvesting.—If not planted too thinly Amber Cane or Sudan Grass can be mowed and cured as hay. Either of these crops can be allowed to mature to be put into the silo if conditions warrant. When made into hay the crop should be raked, after allowing partial drying in the swath, immediately cocked and allowed to cure in the cock. Often Cane and Sudan Grass may be harvested with the grain or corn binder. The bundles are much more easily handled than the loose hay.

GRAIN SORGHUMS

The grain sorghums for the most part require a longer season to properly mature than Amber Cane or Sudan Grass. The following varieties of grain sorghums have been tried in an experimental and

Kafir grown at Akron, Colorado

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practical way: Kafir, Milo, Kaoliang, Shallu, and Feterita (Sudan Dura). Each of these crops is represented by a large number of varieties.

Of the Kafirs, the Black Hulled White Kafir has been the best. Black Hulled White Kafir can only be matured in Colorado in the extreme southeastern part of the State and in a narrow belt extending along the eastern border practically as far north as Wray. It can be used for a forage considerably further west.

There is only one type of Milo that should be grown in Colorado, and that is the Dwarf Yellow. The tall Milos require too long a season. Dwarf Yellow Milo, in Colorado, is the earliest maturing of the grain sorghums and can be grown farther north and west and at higher altitudes than any other grain sorghum, now grown. In Kansas, Oklahoma, and Texas, Feterita is as early or earlier than Dwarf Milo, but in Colorado the situation is reversed—Dwarf Milo, will mature in a shorter season than Feterita.

Brown Kaoliang is very promising for many sections. It has been possible to mature Kaoliang at higher altitudes and in cooler situations

Brown Kaoliang grown at Akron, Colorado

than other grain sorghums. It has about the same feeding quality and value as the Kafirs. Milo and Feterita are better adapted where the season is long enough to mature them. In very dry situations with excessively short seasons, Kaoliang may have a place. In such locations corn does not thrive and other sorghums are not adapted.

Shallu has been tried and gives some promise. At the present time, however, the Kaoliangs and Shallu can not be recommended for

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the Colorado Plains as strongly as Kafir and Milo. It is advisable to confine the grain sorghum production largely to those two crops.

Feterita is a white seeded crop, resembling Milo very much, except that the heads are always erect. Milo and Feterita belong to the group of sorghums known as Duras. Feterita was first tried in Colorado under the name of Sudan Dura. It is adapted to practically

Feterita grown at Akron, Colorado

the same territory that Milo is adapted. It is more drouth resistant than Milo, but is somewhat more adversely affected by the cool climate. As a consequence, Milo is to be preferred for planting.

Methods of Planting.—All of the grain sorghums should preferably be planted in rows whether it is expected they are to be used for grain or forage. The rows should be at least 3½ feet apart. The rate of planting should be such that Kafir should have a space of 8 to 10 inches between plants—in very dry situations 12 to 15 inches; Feterita should be planted about as Milo. This rate of seeding will require 5 or 6 pounds of seed per acre ordinarily. For planting, an ordinary corn planter can be used provided with Milo plates. If Milo plates are not at hand, blank plates can be made into Milo plates by having a blacksmith drill holes of the proper size and spacing.

In the hotter, dryer sections of the Plains the grain sorghums will produce heavier yields of forage than corn. In such sections they should be grown for the silo or for fodder in preference to corn.

Harvesting.—When harvested for forage, these crops should be made into fodder, or preferably siloed. They should be allowed to

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stand in the field under ordinary conditions until the seed is practically ripe. If put into the silo earlier, they will not make as much feed and there is a tendency to the formation of a sour silage.

In addition to being valuable for forage, the seed of the grain sorghums is valuable for feeding to all kinds of animals. It is possible to feed the seed of Amber Sorghum, but it is usually not advisable. The seed coat of Amber Sorghum is very hard and impervious to moisture. As a consequence Amber Sorghum seed is very much more difficult for the animals to eat than the seed of grain sorghums. Besides, the grain sorghums, where adapted, will produce a heavier amount of seed.

Milo and Fetera, when mature, have rather woody stalks and do not make a good fodder. They make a good silage, however. For fodder purposes, Kafir is a much superior grain sorghum. If hay alone is desired, it is better to grow Sudan Grass or Amber Sorghum than any of the grain sorghum varieties.

Harvesting for Seed.—When it is desired to harvest the grain or seed of the grain sorghums, it is best to allow the crop to get ripe, then, if possible, to cut with a binder and shock.

For feeding purposes the fodder having the ripe seed can be run thru a thrashing machine as soon as the stalks are well cured. Where the seed is to be used for seed, the heads should be picked out and stored under cover. Any of the grain sorghums, if stored in bulk, are very liable to heat, and only a very slight heating is necessary to render the germ infertile. Where a corn binder is not possible, the crop can be harvested by cutting by hand or by the use of a cutting sled. These methods are more economical of time and labor than to attempt to harvest the heads separately in the field. For seed purposes only it is possible to economically harvest heads from desirable plants in the field.

MILLETS

Owing to the fact that they will develop with relatively small moisture supplies and that they will mature in a short season, Millets must be considered among the important dry land forage crops. Millets, as are the sorghums, are "hot weather" crops and will not do well at higher and cooler altitudes. For the most part their place among the dry land forage crops is to furnish hay for horses, cattle and other similar livestock.

Varieties.—The varieties commonly met with on the Plains are the German, Common, Hungarian, Siberian, and Hog Millet. Hog Millet is grown more frequently for the grain than for the forage. In some sections it will produce quite heavy yields of seed. It is not widely adapted for Colorado Plains conditions. Where it is adapted it is worthy of a place in the rotation. Elsewhere, it should not be grown at all. Most of the sections where it does well lie in the northeastern part of the state.

In general, German Millet is recommended in preference to others. It grows more rank than the Common and consequently, where moisture supplies are fairly good, should be seeded a little thicker. If this pre-

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caution is taken it will make as fine hay and usually a little more tonnage than Common. The other varieties are adapted, but do not possess any superiority. As a consequence, planting for hay purposes should be limited to the German and Common.

Preparation of the Soil.—The soil for millets must be prepared as thoroly, or more thoroly, than for sorghums and corn, as it is small seeded and must have a comparatively congenial seed bed if it is to produce a good crop. In order to accomplish the production of such a seed bed, plowing should be very early in order to allow the accumulation and protection of the moisture supply.

Seeding.—Millet should not be seeded until approximately the first of June for most of the Plains territory. It will not develop in a cold soil, and since it matures in a short season, planting can be delayed until the soil is thoroly warm, which is about the first of June. Preferably the seed should be put in with a press drill, using about 25 to 30 pounds of seed per acre. It can, however, be seeded by broadcasting and harrowing the seed in, or better still, rolling it in and following the roller with a harrow.

Harvesting.—Millet makes a valuable hay if it is cut at the right time. The right time is about the time the seed is in the milk. It allowed to mature farther than this the seed is liable to injure livestock to which it is fed. This is especially true of horses. When cut at the proper time, just as the seed is reaching the milk it makes a palatable, nutritious hay. The hay can be cut and allowed to partly cure in the swath, raked and cocked for complete curing. As soon as thoroly cured, it should be stacked to prevent loss.

SWEET CLOVER

In Colorado, Sweet Clover has been considered a weed and a serious pest until very recently. Many, however, are coming to recognize that this crop has value. As a soil renovator there is no legume which will give as desirable and quick results as will Sweet Clover. It finds an excellent place in pastures, and when cut at the proper time makes a nutritious, palatable hay. Feeding experiments at a number of experiment stations have shown that Sweet Clover hay, cut at the right time and properly cured, will give equal results with alfalfa hay. There is a little more waste usually with Sweet Clover than alfalfa, but for the pounds consumed, just as good returns in meat or milk production are received.

Sweet clover is usually well adapted for the sandier sections and should be planted rather freely in native pastures. In many places where it is difficult to start alfalfa, or to get a crop of alfalfa, Sweet Clover will make a profitable legume crop in place of it. It can be planted in rows similar to row alfalfa, or planted broadcast. It is sufficiently valuable to be given a thoro trial wherever there is difficulty in growing alfalfa in rows. Probably in those localities where alfalfa does well in rows, it will not be worth while to grow Sweet Clover for hay, but even in such localities it will be well to attempt getting the crop started in pastures. If rightly managed, it will be possible

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to materially increase the carrying capacities of many native pastures.

Varieties.—There are three varieties of Sweet Clover that may be encountered. The White Sweet Clover *(Melilotus alba)*; the Yellow Sweet Clover *(Melilotus officinalis)*; and Small or Annual Sweet Clover *(Melilotus indica)*. The two first named varieties are biennial, that is the plants live two years. The third variety is an annual. The Annual Yellow Sweet Clover has no value for pasture or hay as it is very small growing and is less palatable than the other two varieties. For the most of the territory, White Sweet Clover is greatly to be preferred. It is a better hay crop as it grows taller, and stands more erectly. Yellow Sweet Clover does not grow so large and has a more spreading habit of growth. While it is less well adapted for hay, there are some localities where it will do better than the White, notably in extremely high altitudes. In the Platte-Arkansas Divide country at altitudes above 7,500 feet, Yellow Sweet Clover is preferable to the White as it will mature in a shorter season. Yellow Sweet Clover is better for pasture purposes than for hay purposes.

Soil Preparation.—When seeded for a hay crop or when seeded upon old lands, the soil should be prepared exactly as for alfalfa. When seeded in native pastures or in sandy regions among native grasses it can frequently be seeded on the snows in the winter time, or seeded early in the spring and harrowed. Usually this will give sufficient covering to permit the crop to start. Sometimes on land having a rather heavy sod, running over the land with a disk set rather straight, followed with a harrow, is found to be good practice.

Seeding.—Sweet Clover may be seeded in the spring or fall. There is little danger of its being injured by frosts. It can therefor be seeded as early in the spring as the land can be prepared and conveniently worked. Eight to 10 pounds of hulled seed are a great plenty for dry land conditions. Fifteen to 20 pounds of the unhulled seed should be used to make approximately the same stands. Sweet Clover has many so-called hard seeds, which germinate slowly. In this case the "hard seeds" are viable, but the seed coat is impervious to water. Owing to this "hard seed" condition, it is often possible to plant in the fall and get better stands than from spring seeding.

The crop should be given much the same care as alfalfa. The first cutting should not be made until the sprouts which are to produce the following crop commence to appear. Usually one crop can be received the first year if there was sufficient moisture in the seed-bed to properly start the development and maintain the growth thru possible dry spells. The second year two cuttings should be received. except in very drouthy years. The cutter bars should be set high in cutting the second year crop in order not to kill the plants. The plants start out from sprouts which come out on stalks close to the

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ground. If cut below these sprouts the crop will be killed. If cut high there will be no danger of this.

Sweet Clover becomes very woody and a bitter principle *(cumerin)* which it contains is very strongly developed as the plant approaches full bloom. Consequently care should be taken to cut the crop as soon as the shoots for the next crop commence to appear. If this is done a more palatable hay of a very much less bitter quality with less waste will be produced.

THE GRAINS FOR HAY

A large use is already being made of many of the grains for both hay and pasture. Winter wheat and rye each make fairly good late fall and summer pasture. These two grains are the only ones at all well adapted for pasture purposes, but they are very well adapted for dry land annual pastures. In the cooler regions, and in the northern and northwestern parts of the Colorado Plains, rye is probably preferable. In the warmer portions, winter wheat will be preferable. Wheat, oats, beardless barleys, rye and emmer will each make a good quality of hay if harvested when the seed is in the milk or soft dough stage. Often these crops will make profitable hay yields, the season taken into consideration, when the grain which is produced upon them would not be worth harvesting.

When grown for hay, these crops are planted and cared for as they would be for grain. For pasture purposes, winter wheat, and rye should be seeded in July; for hay purposes the latter part of September is preferable where the crop is to be harvested the following year. Barley and emmer can be seeded in March if conditions are such that the land can be worked. Oats should not usually be seeded until the middle of April at least, on acount of possible injury from late spring frosts. Wheat and rye should be seeded at the rate of about 30 to 35 pounds of seed per acre. Oats should be seeded at the rate of from 40 to 50 pounds; hulless barley should be seeded at the rate of 50 to 60 pounds, and hulled barley at about 60 pounds for hay purposes. Emmer should be seeded at the rate of 60 to 70 pounds. Each of these crops should be seeded with a press drill to obtain best results.

STOCK MELONS

Another source of possible late fall and early winter succulent feed, is Stock Melons. Stock Melons look very much like watermelons, but have a very much thicker rind. Experiments at Eads and Cheyenne Wells show that stock will eat these melons with relish. They make an excellent sod crop and if weeds are kept down will do well on old lands. They are best adapted to the hotter portions of the eastern and southeastern parts of the State. The land should be well prepared, and if sod land, the sod should be rolled flat immediately behind the plow. The melons should be planted in hills at least 10 feet apart each way. On sod land they need very

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little cultivation. On old lands they will need sufficient cultivation to keep the weed crop down.

The keeping quality of the melons is good, if kept from freezing. Thus they may be fed out in the fall as desired, if properly protected from being frozen by straw or other covering.

PEAS

Field Peas or Canada Field Peas are exceedingly well adapted to the high lands of the Platte-Arkansas Divide. They are not well adapted to the relatively lower altitudes of the eastern and southeastern parts of the State. It is possible to grow them, but they are not sufficiently profitable to pay for cultivating them under normal conditions except in the Divide territory.

They should be seeded usually on well prepared land at the rate of 30 to 45 pounds per acre, using preferably a disk drill having a revolving cup type of feed in order not to crush the seed. Planting should be done just as early in the spring as weather and soil conditions will permit, as peas develop best in the cool of the year. Peas will do better at an altitude of 6500 to 8500 feet than they will at lower altitudes, because they develop better in the cool weather of the season. It is this feature which makes them adapted to the Divide, and poorly adapted to the other portions of the Colorado Plains.

VETCH

Vetch has been recommended, but in the experimental work carried on thus far it has not given sufficient returns to pay at all. At the present we cannot recommend Vetch for Colorado Plains planting.

PEANUTS

Peanuts is another crop which has been discussed a good deal and recommended by some for our territory. Peanuts is another hot weather crop. In Texas and Oklahoma and other southern States they do exceedingly well, but so far as experiments show, they do not give sufficient promise in our cool climate, with our short growing seasons, to warrant recommending them for much of our territory. They can be grown and occasionally matured as far in the State as Hugo. They do a good deal better in the extreme southeastern part of the State, but even here are not yet well enough adapted to be unqualifiedly recommended.

BROOM CORN

Broom Corn is very well adapted to the southeastern portions of the State and as far west as two tiers of counties from the eastern border. This crop should not be grown in preference to other sorghums for a forage crop, but in some localities Broom Corn is grown for a cash crop. In such localities if the fodder is harvested it will make a very useful and valuable feed. Except to be used in this way it can not be recommended because it is not so valuable as other adapted sorghums as an exclusive forage crop. Where it is grown

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for the brush, however, it is worth while to take particular pains to save the fodder which can be dry cured or siloed as circumstances permit.

SOY BEANS

Soy Beans can be grown in the Arkansas Valley from Pueblo eastward. Only the very earliest types, however, are adapted. We have succeeded in maturing some varieties at Cheyenne Wells, but the development of the crop was not such as to warrant recommending it for general planting even in that section. This crop may find a place in the extreme southeastern section, as the season is long enough in that region to permit maturing one or two of the earliest varieties. The Soy Bean is capable of withstanding considerable drouth, so it may find some use in that section.

COW PEAS

Cow Peas is a southern crop. While called Cow Peas, they are in reality not peas at all, but a species of beans. They are killed by the very lightest frosts, consequently they are not adapted to any except the extreme southeastern portions of the Colorado Plains, and even there only one or two of the very earliest varieties can be grown. They do not possess sufficient merit to warrant very general recommendations even for this territory. Both Soy Beans and Cow Peas should be planted in rows and cultivated if their growth is attempted. Such a method takes less seed which is very expensive, and under dry land conditions will give as good or better returns. About 20 pounds of seed will probably be sufficient per acre if planted in rows for cultivation. The seeds are rather large and should be planted with a corn planter or with a grain-drill, stopping part of the holes. The revolving cup type of feed will not break or crack many of the seeds.

PASTURES AND NATIVE HAYS

Russian Thistles.—Russian Thistles are one of the worst weeds of the dry lands. They are much worse pests in dry than in wet years. While they cannot be recommended for purposeful planting, there are occasional seasons when they may be utilized to help a deficient supply of forage. The years of 1911 and 1913 had such seasons.

Russian Thistles when utilized return the most feed when properly siloed. They may also be cut, cured, and stacked for hay. The thistles must be cut before the spines get developed and hard, otherwise there is serious danger to the stock to which the thistle hay is fed.

Native Hays.—Many of the native grasses of the Plains make very nutritious hays. But, except in low places or swales, the growth

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is normally insufficient for hay. The Wheat Grasses, Bluestem, and Gramas are the most common native hay species.

Native Pastures.—There are still many places on the Plains where there are large areas of native pasture. Where these native pastures are open range, little may be done to improve their carrying capacity. Where under fence and private control it is possible to very materially improve carrying capacity by letting part of the pasture rest while the other portion is grazed.

Some improvement may often be made by seeding in Sweet Clover. This is especially true of the sandier localities.

In the high Divide country Brome Grass *(Bromus inermis)* does well. Here it may be seeded in the native pastures with a disk drill.

Brome grass grown by Mr. Chas. Green, Leroy, Colorado

The wet valleys in the sand hills often produce Brome quite well. Except under the conditions just mentioned, Brome Grass is very indifferently successful or a total failure.

Tame Pastures.—Tame pastures are among the most serious and difficult problems of dry farming.

No tame grass is ever successful. Brome and Orchard Grass may be grown in the few limited sections above mentioned. But they are not generally adapted. Yet they are the best tame grasses with which experiments have thus far been conducted.

For hog and horse pasture, alfalfa, in rows, may be used. Probably for those animals which may safely be pastured upon it, alfalfa will furnish more feed than any other permanent crop.

Sweet Clover will make some pasture practically anywhere on the Plains, even under conditions too severe for alfalfa.

It may be grazed with greater safety than alfalfa. But it is unsafe to graze Sweet Clover with either cattle or sheep when wet from dew or rain.

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Bulletin 215 November, 1915

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

THE DETHRIDGE METER

By

V. M. CONE, Irrigation Engineer,

U. S. Office of Public Roads and Rural Engineering

This bulletin is based upon work done in the hydraulic laboratory, at Fort Collins, Colorado, under a co-operative agreement between the Colorado Experiment Station and the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture.

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Dethridge Meter Installed for Testing at Hydraulic Laboratory, Fort Collins, Colorado

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THE DETHRIDGE METER

By V. M. Cone, Irrigation Engineer, U. S Office of Public Roads and Rural Engineering.

The Dethridge meter is a device for measuring water flowing in open channels. It is the invention of Mr. J. S. Dethridge, member of the State Rivers and Water Supply Commission of Victoria, Australia, and several thousands of them are in use in different parts of Australia for measuring irrigation water. At the present time few are in use in the United States, except for experimental purposes. In Australia, but one size of meter, the 5-foot wheel, is used, and where it is necessary to measure the flow in a ditch in excess of the capacity of a single meter, two or more wheels are placed side by side with walls between them to divide the flow.

For the purpose of better adapting the Dethridge meter to irrigation conditions in the United States, three sizes of wheels, with no essential changes in Mr. Dethridge's design, were experimented with at the hydraulic laboratory at Fort Collins, Colo., during the summer of 1915. The statements in this bulletin are based on these experiments.*

The meter consists of a drum with projecting vanes so placed in the box or structure in the ditch that there is a uniform clearance of from one-fourth to three-eights inch between the walls of the box and sides of the wheel, and also between the vanes and the curved floor of the box. Spokes made of 2x4 lumber are placed inside the drum; one set of spokes in each end of the drum for the smaller sizes, and a third set in the middle for the largest sized drum.

A horizontal shaft made of one-inch pipe is placed through the spokes at the center of the drum and this shaft is supported in a horizontal position by 4x4 wood block bearings. A bearing made by boring a hole in a 4x4 block of wood is durable and entirely satisfactory if oiled occasionally. A large nail placed through a hole bored in the pipe shaft and stapled to one of the spokes will prevent the wheel from turning on the shaft. It may be necessary

*Other experiments with this meter have been made by the Office of Experiment Stations in co-operation with the University of California at Davis, Cal., the results being published in California University Agricultural Experiment Station bulletin 247.

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to place a washer on each side of the wheel between the spokes and the wall, to prevent the wheel from rubbing the sides.

A cyclometer or bicycle counter made of rust resistant metal, which may be purchased for $1.00 or less, is fixed in a recess in the side of the wall near one end of the shaft as shown in Fig. 1. A sixteen penny nail placed through a hole drilled in the shaft about a quarter of an inch from the end of the shaft, serves as a pin to turn the counter. Injury to or intereference with the counter is

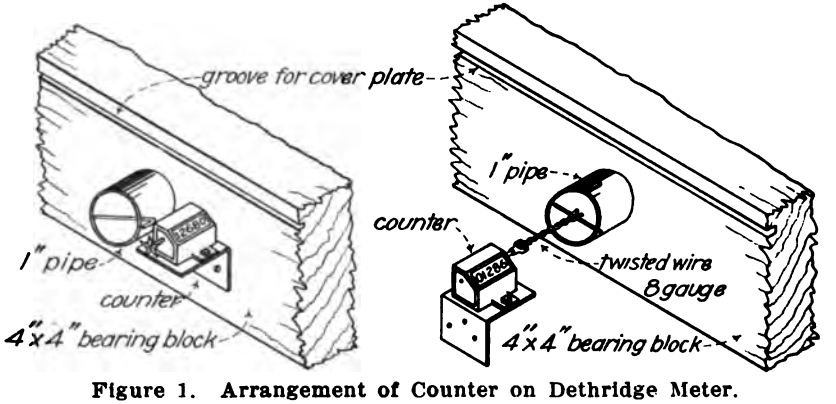

Figure 1. Arrangement of Counter on Dethridge Meter.

prevented by a sheet metal plate, one edge of which is set in a groove in the bearing block, and the other edge is held by a staple and padlock.

The sheet metal work on the wheel, Fig. 2, is not especially difficult, but it should be made in a shop where the necessary machinery is at hand. The cost of the wheels used in these experiments was $23, $25 and $27.50 for the 4, 5 and 6-foot diameters respectively. These costs were for the wheels complete with axles, and as they were made largely by hand, it is certain that the prices could be lowered from $5 to $10 if made in lots of twenty or more.

The box or structure which contains the wheel, Fig. 3, may be made of wood or concrete. Concrete is to be preferred where practicable, for it insures the proper clearance being maintained between the wheel and the box. It is the practice in Australia to make the box of concrete sections, which are cast in a central place, seasoned, and cemented together after being hauled into the field where wanted.

The Dethridge meter has many points of advantage. It is simple, easily understood, records the flow under varying conditions, requires little loss of grade for operation within its normal

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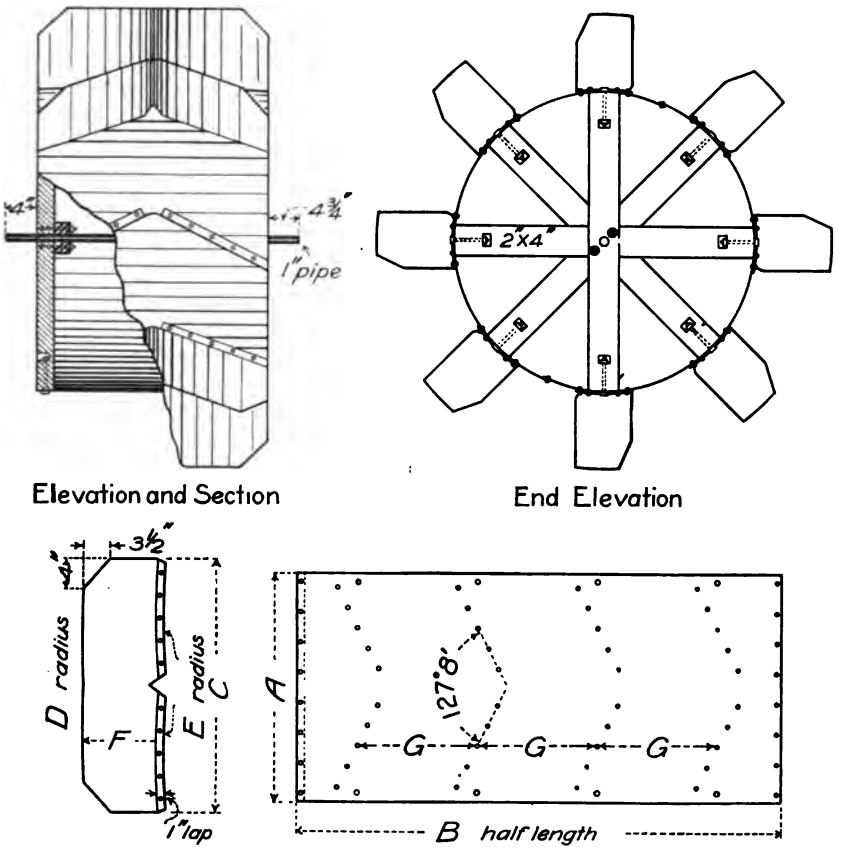

Development of Vane and Drum Sheets

Figure 2. Details of Wheel for Dethridge Meter.

capacity, is free from sand and silt trouble, and has no delicate working parts. Its one principle disadvantage is that any large piece of floating trash, such as a Russian thistle, will be liable to clog the wheel, and result in damage by causing the water to top the ditch bank. Blocks of wood or other floating trash may float into the space between the blades and the drum, and be carried under without damage, but if the trash is caught by the edge of the vane, it will be carried down and wedge on the floor.

The wheel may be lifted to allow the ditch to be cleared of trash when water is first turned in each season. It is advisable to place a Dethridge meter not far from the headgate, for this offers the least liability of trash being collected in the ditch, with resulting interference with the operation of the wheel.

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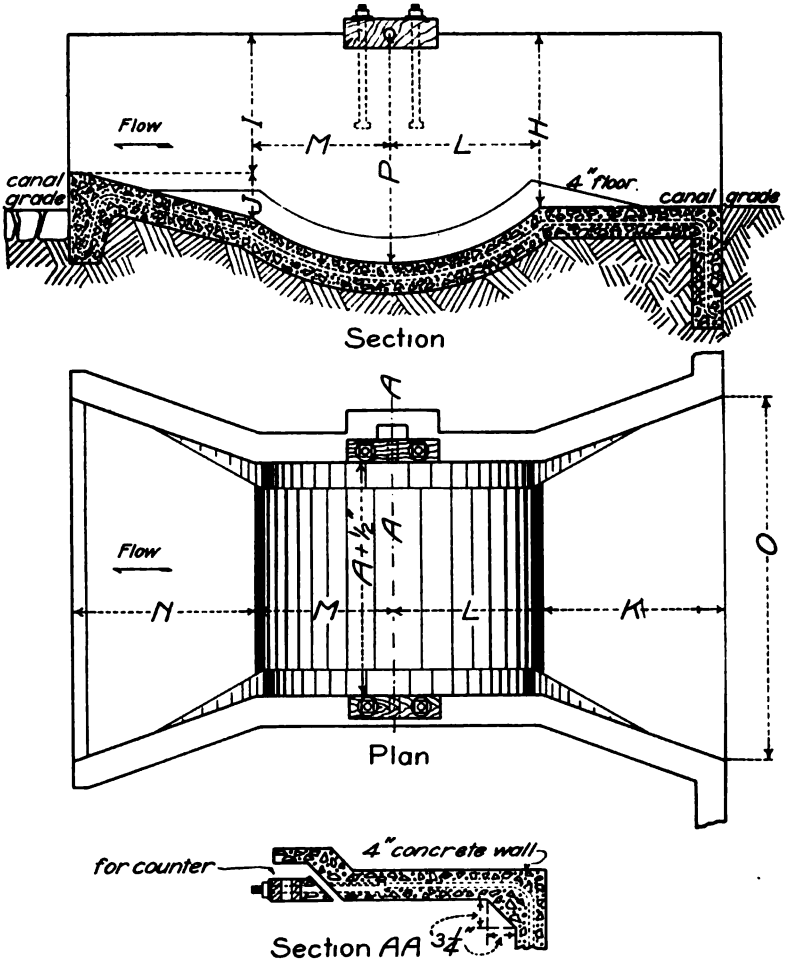

Figure 3. Details of Box for Dethridge Meter.

The speed of the wheel varies with the flow of water in the ditch. If the wheel should fit the structure so as to leave practically no clearance, except to allow a free motion of the wheel, each revolution would deliver exactly the same volume of water regardless of the speed of the wheel or depth of the water in the ditch. The clearance of one-fourth of an inch allows some water to slip by, and this slippage changes with the depth of water in the ditch, and the difference in the depth on the upstream and downstream sides of the wheel. The actual volume which passes the wheel is therefore greater than the volume required to fill the space between the vanes and the drum. and the curves shown in the accompanying

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TABLE 1—DIMENSIONS OF DETHRIDGE METERS.

(Letters Refer to Figs. 2 and 3.)

	SIZE OF WHEEL.		
	—4 Feet—	—5 Feet—	—6 Feet—
A.....	2′ 0 ″	2′ 6 ″	3′ 6 ″
B.....	4′ 3¼ ″	5′ 3¾ ″	6′ 4⅜ ″
C.....	2′ 2¾ ″	2′ 9½ ″	3′ 10⅞ ″
D.....	10′ 0 ″	12′ 8 ″	15′ 0 ″
E.....	6′ 8 ″	8′ 5 ″	10′ 0 ″
F.....	8 ″	10 ″	12 ″
G.....	1′ 0 9/16″	1′ 3 11/16″	1′ 6⅞ ″
H.....	1′ 7 ″	1′ 11 ″	2′ 3 ″
I.....	1′ 3 ″	1′ 6 ″	1′ 8 ″
J.....	4 ″	6 ″	9 ″
K.....	2′ 8 ″	2′ 0 ″	3′ 0 ″
L.....	1′ 2¾ ″	1′ 7½ ″	2′ 1 ″
M.....	1′ 1¼ ″	1′ 6½ ″	1′ 10¼ ″
N.....	2′ 6 ″	2′ 0 ″	3′ 0 ″
O.....	4′ 0 ″	4′ 0 ″	5′ 6 ″
P.....	2′ 0¼ ″	2′ 6¼ ″	3′ 0¼ ″
*.....	2′ 9 ″	3′ 3 ″	4′ 3 ″

*Length of 1-inch pipe for axle.

diagrams represent the average condition. The irregularity of the points in Fig. 4 plotted from the experimental values is not due to error, but is due to changed conditions of flow in the ditch during the several experiments.

Experiments were made to determine the effect of various changes in the shape of the box. The uprising lip of the floor was eliminated and the wheel was set lower in the ditch to give the same submergence of the vanes, but this change resulted in no advantage whatever. It interfered with the flow of the water, and decreased the capacity of the wheel as much as 20 per cent.

The normal capacities of the 4, 5 and 6 foot diameter wheels are ¾ to 2½ second feet, 1 to 4 second feet and 1 to 8 second feet respectively. They may carry an additional 1 or 2 second feet, but there is a greater loss of head, and the force of the blades is such as to splash water over the sides of the box. It also results in excessive washing of the banks below the box. The wave action caused by the wheel under normal operation requires some bank protection below the box.

The principle value of the Dethridge meter is that it integrates or adds up all the water that is passed through the meter, regardless of any changes that may have occurred in the rate of flow, and it also keeps a record of the total amount. It is therefore, a total flow meter, but may also be used to indicate the quantity flowing at any certain time.

To determine the quantity of water flowing through the meter at any time, count the number of revolutions of the wheel in one

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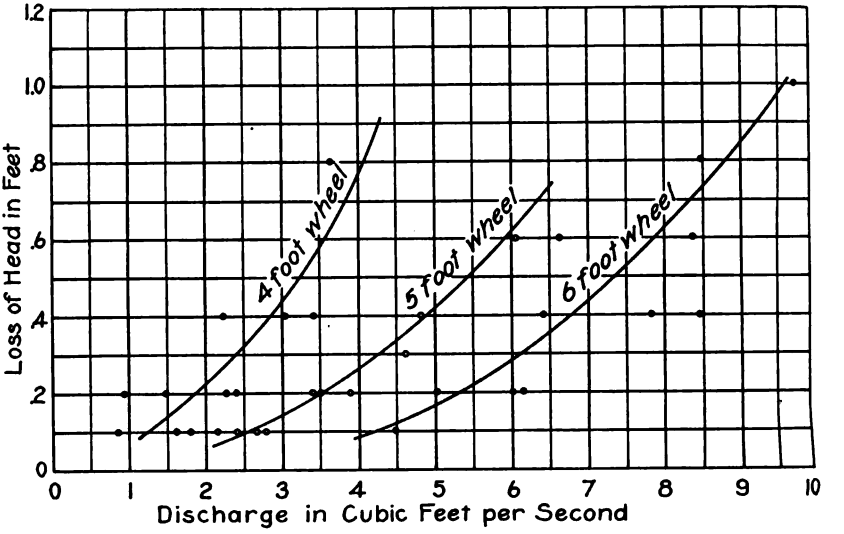

Figure 4. Loss of Head for Different Flows Through Dethridge Meter.

minute, locate this number on the vertical scale in Fig. 5, follow along this line to the right until the curve is reached for the size of wheel used, then follow straight downward to the bottom line where the discharge in second feet will be found. For example, 9.5

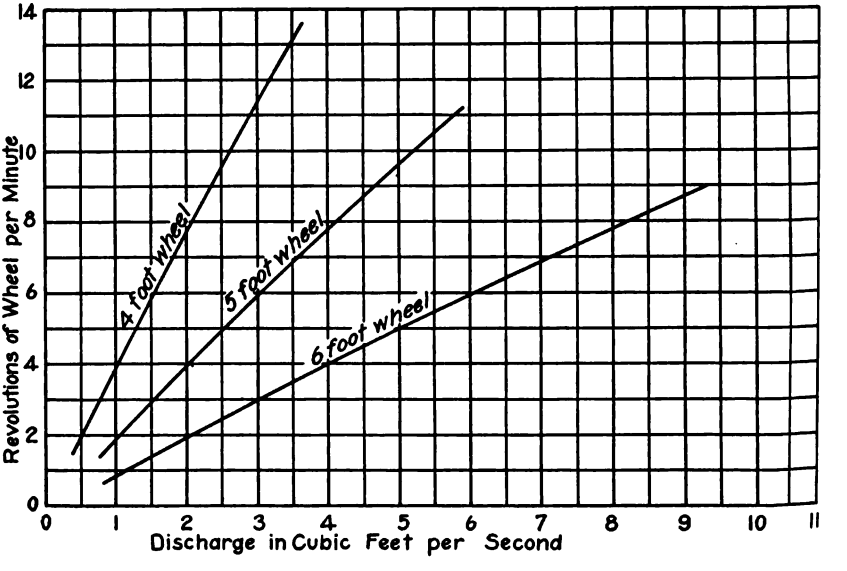

Figure 5. Water Passing Dethridge Meter with Wheel Turning at Different Speeds.

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revolutions per minute for a 4 foot wheel gives a discharge of 2.5 second feet.

Fig. 4 shows the approximate loss of head or drop of water surface which will be necessary to allow different quantities of water to flow through the meter. These curves are of use in deciding what size of wheel to install to meet any certain ditch condition.

To determine the total quantity which has flowed through the meter during any certain period of time, take the difference between the counter readings at the beginning and termination of this period, and multiply this difference by the fraction of an acre inch of water delivered by each revolution of the wheel, as shown in Fig. 6. For example, if the counter reading at the start it 21695 and at the stop is 23825, the wheel made 2,130 revolutions. If the wheel is 6 feet

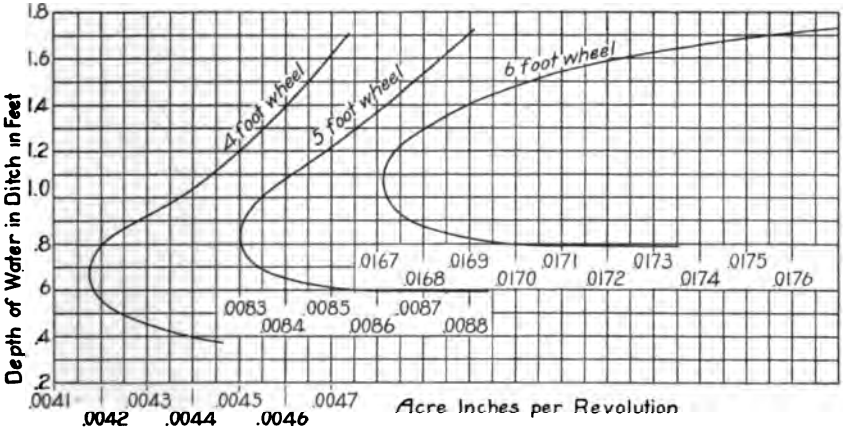

Figure 6. Rating Curve for Dethridge Meters. For Converting Revolutions of Meter into Acre Inches of Water Delivered.

in diameter and the average depth of water in the ditch upstream from the wheel was 1.4 feet, it will be seen in Fig. 6 that each revolution of the wheel has delivered .0169 acre inches of water. Multiply 2130 by .0169 and the result is 36 acre inches or three acre feet of water. If six acres were irrigated, the land was covered to an average depth of 6 inches.

It is necessary that the wheel and box of the Dethridge meter, as well as the clearance between the vanes and the box, be the same as given in the accompanying plans, if the rating curves given in Fig. 6 are to be used. Under ordinary conditions of canal operation a Dethridge meter should register the flow with an error not exceeding 2 per cent, and even under unusual ditch conditions, but with proper construction of the meter, the error should not exceed 5 per cent.

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Bulletin 216 November, 1915

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

STUDIES OF HEALTH IN POTATOES

By C. L. FITCH

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1915

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STUDIES OF HEALTH IN POTATOES

By C. L. FITCH

In July and August of 1911 it became apparent that every potato plant in the fields attacked, and nearly every field in two of the great potato-producing regions of Colorado, had been crippled by the leaf-roll disease. One of these regions was on the plains and subject to very warm and continuous sunshine. The growers of the other district had been purchasing most of their seed potatoes from the first region and their potato fields were subject to considerable soakage, due to their system of irrigating by filling the subsoil with water to such a level that the roots were supplied with moisture by capilarity. At the same time the crops of potatoes on the mountain mesas throughout the State, even when grown from the same seed, were excellent.

The growers in the first region, the Greeley district, had been unable for years to grow their own seed potatoes for more than one or two propagations and had drawn upon unirrigated regions for their foundation seed supply. For a considerable number of years it had been increasingly difficult to produce tubers of the most desirable shape. While formerly, the second crop of potatoes had been the better because of the improved condition of the soil, at this time the second crop had become very much poorer in quality and less in quantity, and that, in spite of increasing average yields of grain upon the same fields.

In the second region, the San Luis Valley, seed stocks had been maintained more easily, but better results had been secured from small whole potatoes such as were readily obtained from the Greeley district, and of late years the Valley had used such seed for most of its potato fields.

A careful study, at the weather bureau in Denver, of the temperatures throughout the year, and other years, for the stations nearest to afflicted and to healthy potato regions, and of the rainfall, lead to the belief that the factors controlling the appearance of the leaf-roll disease were none other than soil-heat and soakage. Where the fields had been unusually warm and wet the disease had come; where the soil had been cool and not over-wet the plants had been healthy.

A careful field study of potato roots during midsummer revealed the fact that in the warmer regions the roots within six inches

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of the surface were badly diseased as compared to those deeper in the soil. This field study of roots was supplemented later by a study of the root cap and by a study of the potato leaf and its adaptation to an arid climate. It was decided later to study in detail the effect of soil-temperature and soakage upon potato plants grown during the winter of 1911 and 1912 in the College greenhouse (Figure 1).

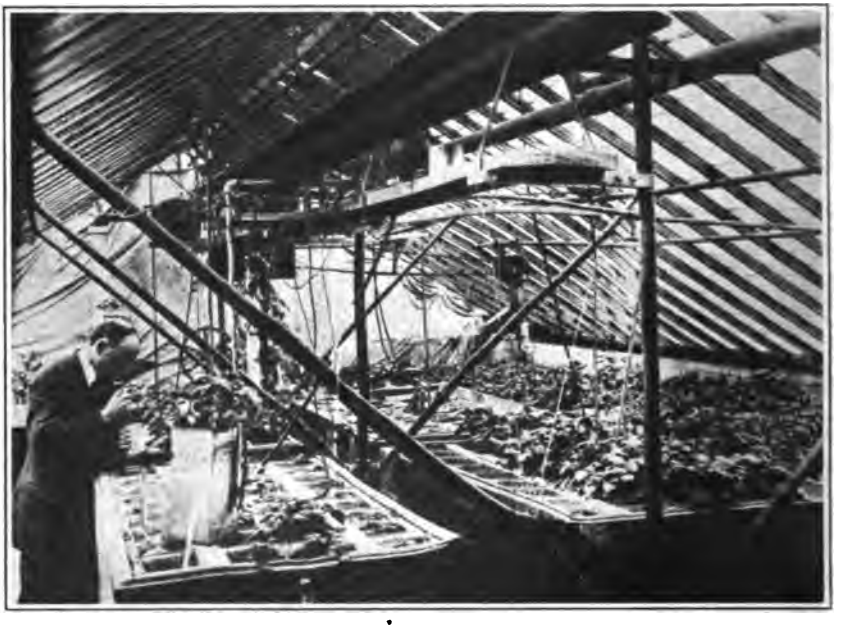

Figure 1.—Greenhouse experiment to determine effect of soil temperature and soakage upon the potato plant.

Careful study was given to the history and practices of the various potato-growing districts, and field evidence was secured which seems to the writer conclusive that the leaf-roll disease in Colorado had, in addition to these causes—soil-heat and soakage—a third cause, probably parasitic and in some way injurious and capable of distribution.

Out of these studies, and out of field studies made later over Iowa, an attempt is made in the summary to make somewhat clearer the essential conditions for health in potatoes and for permanency in potato production. More space is given to detailed reports of observation and experiments, but what may be called evidence-in-

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the-large is regarded as of most value. These studies will be presented under the following heads:

I. Studies of soil temperatures.

II. Studies of potato roots and the potato leaf.

III. Greenhouse studies of the effect of various soil temperatures and percentages of moisture upon potato plants.

IV. Field studies of heat and soakage, and temperatures of soil and of irrigation water.

V. History and practices of potato-growing districts.

VI. The hope and the great difficulty of attempting to secure disease-resistant potatoes.

VII. Summary of what we know of the conditions for potato health and permanent potato production.

I. STUDIES OF SOIL TEMPERATURES.

It was desired to know whether soil temperatures vary greatly in different seasons. The Colorado Station at that time had no soil temperature records but we had recourse to the very complete records kept by the Nebraska Station, and selected for comparison with each other the temperatures at Lincoln for known good years and known years of poor production. Certain of these are summarized below:

MEAN SOIL TEMPERATURES AT DIFFERENT DEPTHS.

(Taken at the Agricultural Experiment Station, at Lincoln, Nebraska, for May, June, July, and August of 1894 and 1901, dry hot years, and for the same months of 1897 and 1902, years of average weather and good moisture supply.)

	1 inch	3 inches	6 inches	9 inches	12 inches	24 inches	36 inches
1894 (Dry year)							
May	63.3	72.7	68.6	66.8	64.7	59.2	59.0
June	78.4	40.1	75.6	73 7	71.5	65.7	62.6
July	86.9	87.6	82.2	80.0	77.9	72.5	68.8
August	88.7	89.2	83.0	81.1	79.8	76.3	72.2
1897 (Good year)							
May	65.9	62.4		61.1	57.7	54.4	52.3
June	76.9	69.7		71.1	65.9	61.5	58.6
July	84.6	82.8		81.1	74.7	68.7	66.2
August	84.4	80.5		79.3	73.9	70.7	68.7
1901 (Dry year)							
May	76.3	75.4	71.6	66.8	62.4	56.6	53.2
June	89.6	88.5	84.0	77.6	72.5	65.1	60.8
July	107.3	102.2	95.3	87.3	81.9	74.1	69.3
August	94.0	92.2	88.4	82.3	78.4	73.7	70.9
1902 (Good year)							
May	75.2	74.6	71.9	67.4	63.4	57.6	54.5
June	75.3	74.3	72.4	70.2	67.4	62.7	61.5
July	82.0	81.8	78.6	75.6	73.2	68.7	66.1
August	79.1	79.3	77.8	74.8	73.1	70.8	68.9

The above records are sufficient to show that drouth is not the only injurious factor in the dry years but that soil temperature may reach an injurious point in such years. If the temperature for July

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of 1901 and 1902 be compared, a great difference is seen. Those for 1901 would be dangerous to all potato roots in the entire upper foot of soil.

Keen observers among the farmers at Greeley were of the opinion that the great injury to the potato crop in 1911 had come during the extreme heat of the month of June. On inquiry, Mr. Max Mendelssohn, agricultural and chemical expert of the Great Western Sugar Company, told us that when he first came to the arid country from Germany, he had realized that a high soil temperature was one of the things to be contended with in beet sugar production. The writer was so fortunate as to secure from Mr. Mendelssohn's associate, Mr. Asa C. Maxson, soil temperatures at Longmont, close to the Greeley district, for 1911 and for the previous year, 1910, a favorable year for potatoes. These temperatures are given below and taken in connection with the Nebraska figures, show conclusively that the whole of the upper foot of soil may be as much as ten degrees warmer one year than another for the whole of the critical month of June, and that, as a matter of fact, such was the case in 1911 as compared to 1910. They show, also, that the cooler years, with more rain and cloudiness and less continuous and intense sunshine, are freer from the extremes of soil temperatures that do the injury. June is the month, in the Greeley district, when potato roots are growing rapidly in the upper foot of soil and when the leaves do not, as yet, afford much shade to the soil.

SOIL TEMPERATURES AT LONGMONT, COLORADO, 1910, TAKEN BY ASA C. MAXSON.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
June 1	61	81	58	75
June 2	72	82	64	69
June 3	41	50	50	63
June 4	49	82	57	68
June 5	51	71	57	66
June 6	59	69	51	64
June 7	59	90	52	73
June 8	72	87	61	76
June 9	64	86	54	77
June 10	63	80	55	73
June 11	58	94	55	81
June 12	60	74	59	68
June 13	64	65	57	63
June 14	59	90	54	72
June 15	70	82	63	74
June 16	69	69	64	68
June 17	68	82	58	73
June 18	71	99	64	85
June 19	76	106	69	85
June 20	70	90	66	80

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SOIL TEMPERATURES AT LONGMONT, COLORADO, 1910—Continued.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
June 21	70	91	67	86
June 22	69	84	68	81
June 23	73	92	68	63
June 24	69	67	69	69
June 25	59	87	66	77
June 26	64	97	70	85
June 27	67	91	64	86
June 28	68	82	66	81
June 29	68	82	65	79
June 30	59	77	61	71
Averages	**64**	**83**	**61**	**70**
July 1	66	82	64	79
July 2	68	77	62	84
July 3	66	84	67	81
July 4	72	77	73	82
July 5	73	77	68	77
July 6	69	95	65	86
July 7	82	100	75	90
July 8	73	104	68	88
July 9	68	72	69	70
July 10	64	81	64	76
July 11	64	82	74	77
July 12	64	79	63	80
July 13	63	75	63	76
July 14	73	108	68	89
July 15	76	106	72	91
July 16	73	92	70	86
July 17	73	101	73	88
July 18	77	98	72	88
July 19	79	86	77	86
July 20	73	86	74	82
July 21	75	93	73	88
July 22	72	90	73	86
July 23	75	106	75	95
July 24	72	97	76	93
July 25	72	105	73	93
July 26	72	99	73	94
July 27	83	77	77	85
July 28	59	68	73	77
July 29	59	59	68	68
July 30	61	83	62	73
July 31	72	99	62	82
Averages	**71**	**88**	**70**	**83.5**
August 1	73	90	70	85
August 2	77	88	68	81
August 3	72	102	68	87
August 4	68	59	68	72
August 5	58	56	69	70
August 6	61	86	62	79

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SOIL TEMPERATURES AT LONGMONT, COLORADO, 1910—Continued.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
August 7	59	81	59	75
August 8	63	73	63	72
August 9	54	86	59	73
August 10	63	77	59	77
August 11	70	82	68	75
August 12	68	81	68	79
August 13	68	81	63	73
August 14	64	86	59	73
August 15	68	91	61	78
August 16	59	76	60	74
August 17	60	63	61	64
August 18	49	91	59	79
August 19	68	86	63	79
August 20	75	82	68	77
August 21	79	88	63	79
August 22	75	88	68	72
August 23	72	73	68	77
August 24	64	68	64	75
August 25	52	75	58	70
August 26	50	97	54	76
August 27	70	102	68	95
August 28	59	100	59	95
August 29	61	93	70	97
August 30	59	73	61	72
August 31	54	86	59	73
Averages	**64**	**83**	**64**	**78**

SOIL TEMPERATURES AT LONGMONT, COLORADO, 1911. TAKEN BY ASA C. MAXSON.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
June 1	62	81	67	73
June 2	66	81	64	79
June 3	72	90	70	82
June 4	79	88	72	83
June 5	75	90	72	86
June 6	77	90	73	84
June 7	81	84	70	84
June 8	79	94	72	86
June 9	75	94	70	86
June 10	81	97	71	88
June 11	83	104	74	90
June 12	83	97	75	90
June 13	83	97	75	88
June 14	81	89	67	82
June 15	74	74	77	74
June 16	72	84	68	77
June 17	77	93	68	85
June 18	77	91	71	86
June 19	81	95	73	88

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SOIL TEMPERATURES AT LONGMONT, COLORADO, 1911—Continued.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
June 20	77	82	76	80
June 21	84	86	71	81
June 22	82	95	70	86
June 23	81	97	73	88
June 24	84	89	75	83
June 25	74	90	72	75
June 26	..	..	73	87
June 27	79	89	75	89
June 28	79	95	78	86
June 29	81	95	77	84
June 30	77	96	76	90
Averages	**78**	**94**	**72**	**84**
July 1	72	82	70	77
July 2	..	84	..	83
July 3	75	89	68	83
July 4	82	88	73	83
July 5	77	84	72	80
July 6	77	92	72	83
July 7	83	88	74	84
July 8	70	97	70	84
July 9	70	97	70	84
July 10	81	97	72	86
July 11	82	97	75	88
July 12	83	98	77	90
July 13	82	91	79	87
July 14	84	101	77	91
July 15	83	85	78	84
July 16	77	86	72	80
July 17	75	98	71	88
July 18	79	80	75	80
July 19	73	79	71	75
July 20	74	98	69	87
July 21	79	92	75	86
July 22	83	92	76	87
July 23	77	95	..	..
July 24	73	88	73	82
July 25	77	..	72	..
July 26	80	97	76	88
July 27	83	92	76	89
July 28	81	92	76	87
July 29	83	98	75	90
July 30	82	95	77	89
July 31	82	91	74	87
Averages	**79**	**90**	**74**	**85**
August 1	81	92	75	87
August 2	80	88	76	83
August 3	77	93	73	86
August 4	75	89	71	84

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SOIL TEMPERATURES AT LONGMONT, COLORADO, 1911—Continued.

Dates	At Two Inches		At Six Inches	
	8 A. M.	5 P. M.	8 A. M.	5 P. M.
	Degrees F.	Degrees F.	Degrees F.	Degrees F.
August 5	79	95	74	85
August 6	78	95	76	88
August 7	88	99	77	90
August 8	84	101	77	90
August 9	84	94	78	85
August 10	83	85	78	83
August 11	79	91	74	84
August 12	80	92	74	88
August 13	80	94	75	88
August 14	80	99	76	90
August 15	86	94	77	91
August 16	80	83	77	82
August 17	..	..	..	..
August 18	..	..	..	..
August 19	..	..	..	..
August 20	..	..	..	..
August 21	..	..	..	..
August 22	73	81	73	79
August 23	73	87	71	81
August 24	71	74	71	75
August 25	70	90	66	81
August 26	75	88	69	82
August 27	73	81	72	77
August 28	75	89	69	81
August 29	74	86	70	82
August 30	76	95	71	86
August 31	77	90	72	85
Averages	78	89	74	83

II. STUDIES OF POTATO ROOTS AND THE POTATO LEAF.

During the seasons of 1911 and 1912 field studies of potato roots were made at Del Norte, Carbondale, Kersey, Greeley, Fort Morgan and in a dry land district at Haxtum. Holes about 3x10 feet were dug across two rows of potatoes and deeper than potato roots were found, the latter being identified when very small by the taste. The accompanying diagram (Figure 2) illustrates the root habits determined by these studies.

Potato roots in open, well-drained, sandy loams go to a considerable depth, limited apparently by the size of the plant, and extending as much as four feet below the seed piece. In the case of Peachblows the distance *S* to *B* is often as much as five feet. Early Ohios, under the same conditions, go down not to exceed three feet and to the side not to exceed four feet. We found that deep cultiva-

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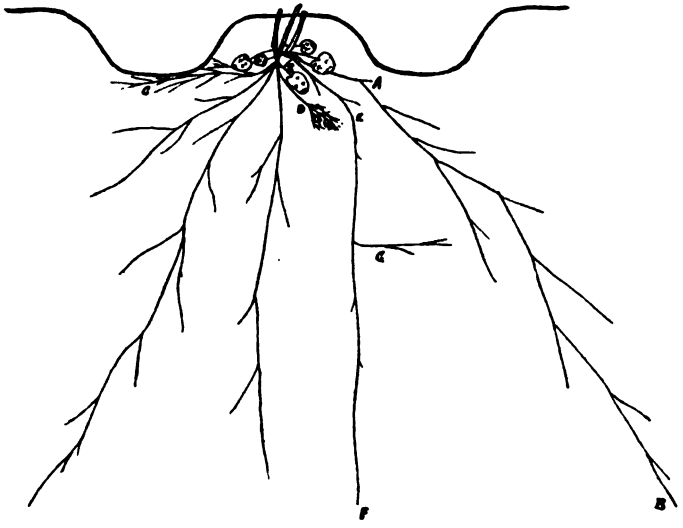

Figure 2.—Diagram illustrating the root habits of potatoes.

tion tends to deeper root growth. A root cut off as at *A* tends to develop branches running deeper. A specially rich spot of earth, or composted manure, stimulates an abundant feeding-root system, as at *D*. After the leaves shade the entire ground and the weather becomes cooler the surface soil is filled with fibrous roots, as shown at *C*. For a full crop, it is important that this richest soil be completely utilized at the end of the growing season. Crops that do poorly early in the season have the least chance to make good because they do not shade the ground as well.

In relation to other roots, particularly those of sagebrush and alfalfa, we found that potato roots seem to gain nothing from the other roots while they are alive, nor before they decay. In recently plowed alfalfa land the soil is more tightly packed about the roots than elsewhere. Potato roots do not go down the alfalfa roots the first year, but the second year the alfalfa roots furnish both food, air and space, and when a potato root reaches a decayed alfalfa root, as at *E*, it goes on down for several feet, as to *F*, and even through soil which the potato root alone would not enter. If, in such heavy soil, there are sandy layers the potato roots enter them as at *G*.

On the dry land we found potato roots stopped by a dry subsoil. The season of 1911 was one of scant moisture and at the time of the studies in 1912 the subsoil, though loamy, was so dry that the potato roots did not enter it, but were confined to the upper two feet, moistened by the rains of 1912. At Carbondale and Kersey we found potato roots stopped by clay. On the E. E. Edgerton mesa farm at Carbondale we found potato roots going less than two

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feed in depth, except where alfalfa or sagebrush roots had gone before. These soils are unexcelled for potato growing because, in

Figure 3.—Photomicrograph of a potato seedling at the stage when the root cap commences to lose masses of cells if slightly rubbed.

Figure 4.—The same seedling as Figure 3, more highly magnified.

our judgment, of the slope, which prevents soakage, and of the climate of the region. In a level and warmer country they probably

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would not grow potatoes permanently. At Ames, Iowa, in the late summer of 1914, Mr. E. E. Isaac, a graduate student, and the writer dug two large holes in a potato field, which has a good deep loam but which is underlaid by clay and which requires artificial drainage. We found, in gravelly loam, potato roots dead at 4 feet, and standing water at 4½ feet; and in heavy clay loam, roots were dead at 3½ feet with water at 4½ feet. The closer-grained soil drew to a higher level water enough to drown the roots. This condition was found in 1912 at Del Norte, Colorado, where a rise in the Rio Grande River had raised the water level under the potato field.

Laboratory studies of potato roots throw an interesting light upon the field studies. The potato root, in the conditions studied, penetrates raw clay soils not at all. This, doubtless, is not only because in such soils a potato root does not find the amount of air which it needs, but also because its root cap (*C* in Figures 4, 5 and 6) is an inefficient protection to the growing tip of a penetrating root. Doubtless potatoes have grown for so many ages in an open soil that their roots are adapted neither to enter nor to live in very close-grained soils. We find that the root cap loses large masses of cells with the slightest rubbing against soft wet paper. As soon as the seedling develops root hairs, the cap will break up, in this manner and the cap on mature plants is similarly weak.

Figure 5.—Germinating potato seedlings, showing loosening of the root caps. These seedlings are from Carbondale Peachblow seeds about 10 years old. Drawing by Ada Hayden.

Figure 6.—The root tip of a potato, showing loose cell cap at tip. Drawing by Ada Hayden.

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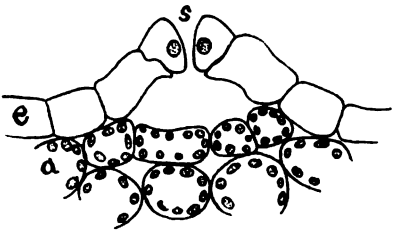

Figure 7.—The stoma or breathing pore of a potato leaf; a structure designed to dissipate rather than conserve moisture. Drawing by Ada Hayden.

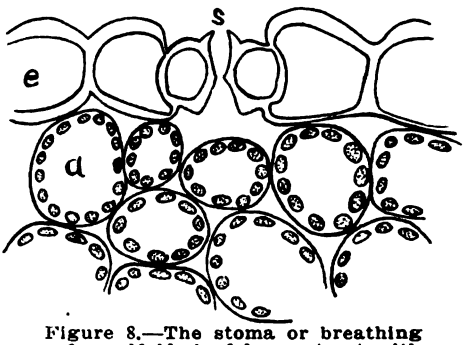

Figure 8.—The stoma or breathing pore of an alfalfa leaf for contrast with that of the potato. A structure designed to conserve moisture. Drawing by Ada Hayden.

Laboratory studies of the potato leaf are of use in studying the needs of the plant. Farmers know that in dark, misty weather potato leaves grow broad and full at the edges and that the crop fairly leaps forward under such conditions. Moisture and temperature conditions in the soil are apt to be right at such times, but the microscope shows that misty weather is particularly good for the leaf itself, and it has been shown, moreover, that starch formation is favored by the less intense light which accompanies such weather. To prove that a damp atmosphere is good for potatoes, we have only to remember the climates of Scotland and of upper Maine.

The stomata, or breathing pores, of the potato leaf (Figure 7) project like little craters and are adapted to the ready escape, on every breeze that passes, of moisture from the scantily protected inner tissues of the leaf. In marked contrast are the stomata of the alfalfa plant (Figure 8) which we know is an age-long native of arid regions. Its leaf openings are protected by being sunken and by having an upper protecting ring about the tiny well. These stomata are adapted to the conservation of moisture.

The evidence of root and leaf seems to prove that the potato plant, if native to mountain regions, must have grown where the soil was deep and open, free from soakage by heavy rains, and where there was much misty weather. That the leaf diseases of the potato—early and late blight—both develop faster in damp weather is evidence of the same sort. The best soil temperatures for potatoes as herein shown have a very narrow range above and below 70 degrees F., and this is very close to the optimum temperature for late blight, which is believed to have lived for ages with

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the potato plant. It seems probable that the potato plant was developed by nature on deep, sandy loams in an equable maritime climate. Our mountain potato districts are among the best in the world because of their cool temperature, pure, cool water, abundant slope, and fertile, alfalfa-filled soils. They would be still better for potatoes if their air was damp.

III. GREENHOUSE STUDIES OF SOIL TEMPERATURES AND MOISTURE.

Following the field evidence that soil heat or soakage, or both, had been the occasion of the leaf-roll disease, arrangements were made for the study of these factors under controlled conditions (Figure 2). A preliminary experiment, in which large incubators heated with lamps were used, having proven unsatisfactory because of the impossibility of securing natural conditions of air and light, four cabinets (Figure 2) were made and fitted with racks, for the suspension, in a water bath, of watertight tanks in which potatoes were planted. Each cabinet held 35 tanks, the space which otherwise would have been occupied by the 36th tank being given to the electrical heating and turbine stirring arrangements shown overhead in Figure 2. Six-hundred-watt heating units, such as are used in electric irons, were soldered to lead pipes which protected the connections. The unit was placed in the water directly beneath the turbine wheel, which was set vertically and arranged to draw the water upwards past the heating unit. Power was furnished by a water motor running continuously. One tank in each cabinet was given to the thermostat which operated the magnets, and these, in turn, cut the heating current out and in. In the coldest cabinet, a geared electric switch was used to open and shut a valve in a pipe supplying mountain water at about 33 degrees F. Except for some weakness in construction of the switches, all the mechanical and electrical parts proved to do their work well. The turbine arrangement was particularly satisfactory and maintained the temperatures in the farthest corners of the cabinets just the same as in the center.

The tanks held 25 pounds each of calculated dry earth. Each empty tank was made up to even weight with coarse sand and this sand was used to mulch the earth and prevent puddling while watering. The tanks and calculated dry earth all weighed the same and a lead weight was made to balance this amount. By sacrificing at intervals some six plants and weighing them, we were able to set, on the second beam of our scales, our plant tare and weigh the

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water direct, on the other beam, each quarter pound being 1%. These calculations were checked at three intervals against samples of earth taken from the tanks with a butter trier and tested for water by drying in a soil oven.

The soil temperatures used were 50°, 65°, 80°, and 95°. The potatoes planted in earth at 95°, in many cases started to sprout but all were killed before coming to the surface, so that only three cabinets were operated to maturity.

The quantities of moisture used were: 10% for the long row at the left in each cabinet through the entire experiment; 20%

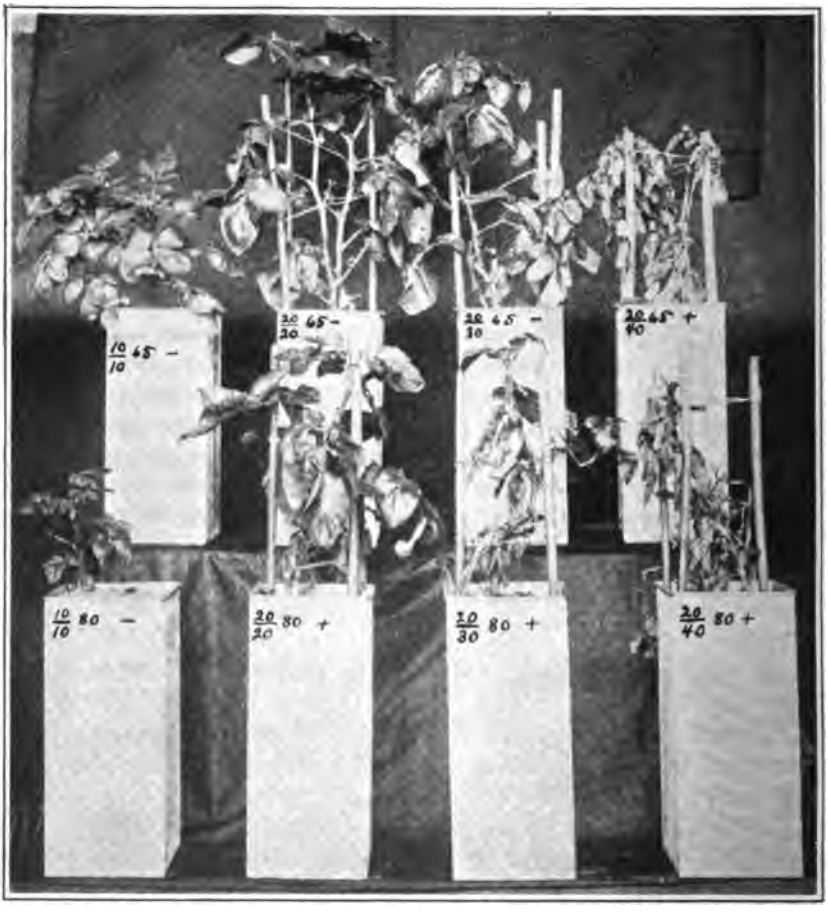

Figure 9.—Plants grown for the whole period respectively at 80 degrees soil temperature (bottom row) and at 65 degrees soil temperature (top row) five days after the right hand plants had been changed from a soil moisture content of 20% to one of 40%, the next plants from 20% to 30%, the left-hand plants remaining at 10% and 20% as from the first. *Fusarium* content negative or positive according to the signs on the tanks.

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for all the period in the second row; 20% for 75 days for the third and fourth rows, and then for 5 days 30% for the third row and 40% for the fourth. We did not dare use 30% and 40% during the main growing period because we believed these high percentages of moisture would cripple the plants (see Figures 9, 10 and 11).

We found that when the moisture in the 10% row fell to 7%, the plants wilted, and that they recovered all right and quickly when watered again. In practice, we ran the water from 2 or 3% above to 2 or 3% below the standard.

The soil used was a mixture, about half and half, of a light, sandy loam from Farmers' Spur near Greeley and clay loam from an alfalfa field on the college farm at Fort Collins. The sandy loam was from a field where leaf-roll had been serious during 1911, and the seed potatoes were Pearls from the same field. The study was made to determine what conditions would bring health and what conditions disease. The potatoes were planted on February 5, 1912, and the temperatures and percentages of moisture were maintained from that date.

The health of the 10% lots, whether in cold, medium or constantly warm soil, was in entire accord with the experience of practical potato growers under irrigation. They find that almost no harm comes in early summer to dry plants, even though the sun be steadily hot and the soil hot. If obliged to irrigate at such times, they do it at night, but the wisest of them often let potatoes get very dark and the leaves droop, hoping for cool weather and showers to put the plants along to where they will shade the ground before irrigating. Then they uniformly practice, on the more level fields, irrigating every other row only, until the vines have reached good size. Some irrigate alternate rows at the second watering and others irrigate the same alternate rows each time until cool weather or self-shade, or both, are at hand. We favor the latter method, because it leaves half of the surface mulched and half of the roots free from soakage while warm.

In times of great scarcity of water less has been used and good crops have been made by irrigating the same alternate rows throughout the season. Dry times are hot times and reservoir water used then is both warm and extremely alkaline. By a principle well known to botanists strong alkalinity makes it somewhat more difficult for the plants to secure water enough for their needs. Conservative irrigation to avoid root injury at such times is imperative for health and a good crop. It is equally reckless in cost

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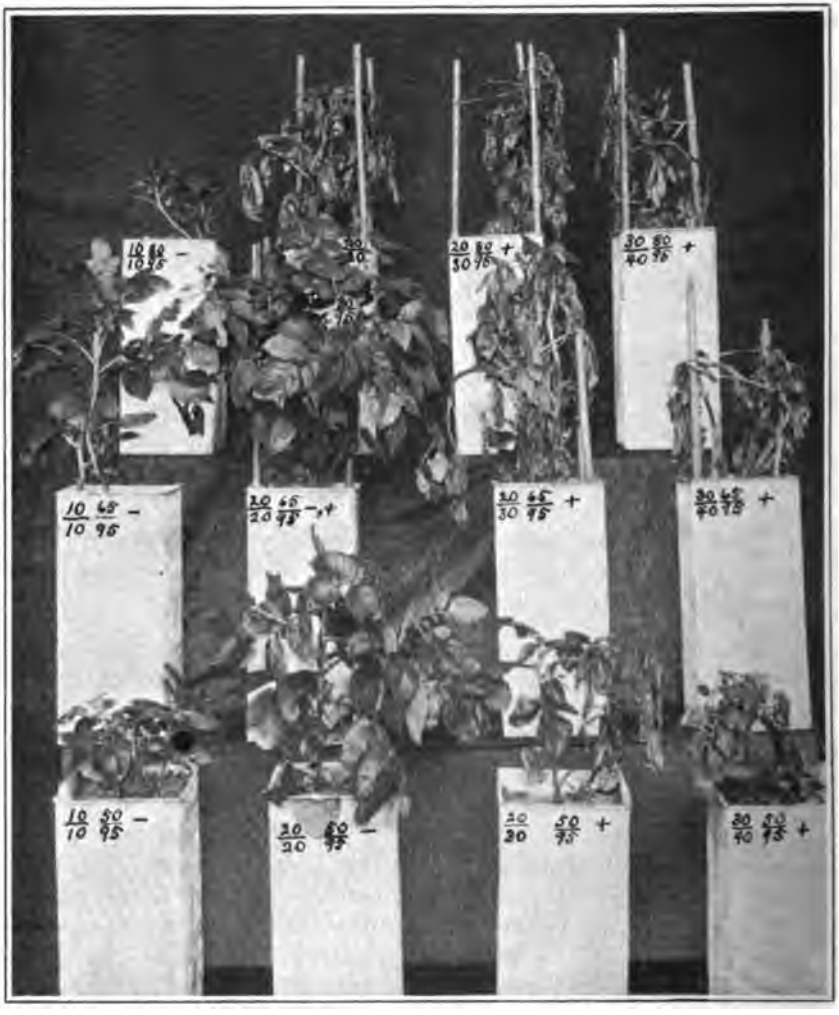

Figure 10.—Plants grown at 80° (top row), 65° (middle row) and 50° (bottom row) for two months and then transferred for five days to a soil temperature of 95°. The right-hand plants were raised from a moisture content of 30% to one of 40%, the next from 20% to 30%, the left-hand ones remaining at 10% and 20% respectively. The *Fusarium* content is marked on the tanks as follows: *Fusarium* found, +; *Fusarium* not found, —.

of water and risk of crop to be prodigal with water on lands with little slope in hot weather.

Observations stated, and to be stated herein, are the basis of the following principle which should govern irrigators of potatoes:

Heat, soakage, infection, continuous cropping with potatoes, alkali water, poor seed, poor fertility are all against potato health.

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The more we have of one condition, the less we can have of the others if we are to make a good crop.

When the higher percentages of moisture were used, the leaves and stems collapsed very quickly, within less than a day, in the 80° cabinet, somewhat less quickly in the 65° cabinet, and not at all in the 50° cabinet. It is to be supposed that the roots were in better condition in the cooler cabinets and were less easily drowned. The effect of the high temperature and soakage was, evidently, the crippling of roots by heat and the exclusion of air, so that the roots could not supply the tops, which then wilted for lack of water.

After 90 days the stems were cut just beneath the soil and were submitted for examination to Professor Walter G. Sackett, of the Colorado Experiment Station. He found a species of *Fusarium* present in some of the stems and absent in others, according to a very definite rule. As the examinations were being made we were able to foretell in advance whether or not the *Fusarium* would be found. The results were absolutely uniform. There were no exceptions.

We regard the presence or absence of the fungus in these experiments as a secondary matter; as an index of the health, or lack of health, of the plants under the conditions to which they

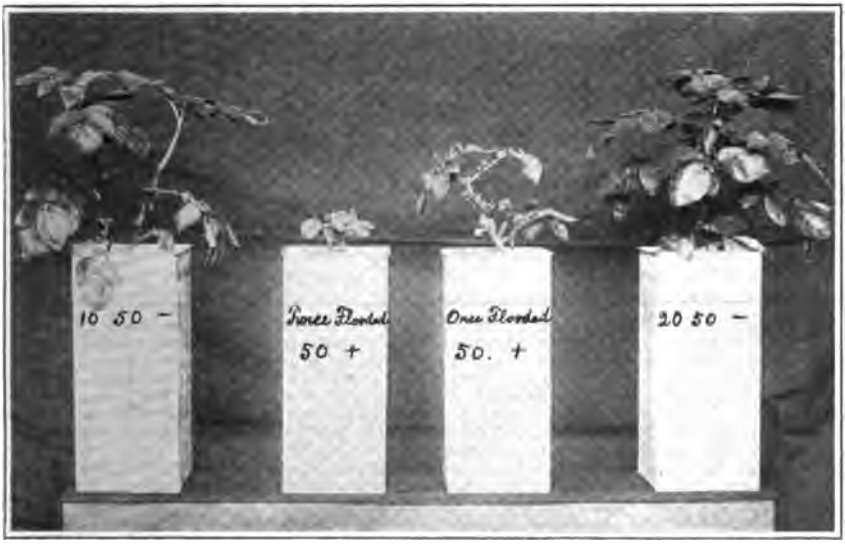

Figure 11.—From left to right: 1. Moisture at 10 per cent (8-12) negative. 2. Twice flooded. *"Rizoc"* and *Fusarium*. 3. Started at 10, once flooded by accident. *"Rizoc"* and *Fusarium*. 4 Moisture at 20 per cent. Check, the same. Both negative. Note the abundant health of the plant on the right, though grown from leaf-roll seed in leaf-roll soil.

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had been subjected. Later herein we shall give the field evidence that there was in Colorado a fungus or infection factor in the leaf-roll disease.

Figures 9, 10 and 11 show the condition of the plants after 80 days of growth. The sign (—) means that *Fusarium* was absent and the sign (+) means that *Fusarium* was found. The first figures are the percentages of moisture used, the second the temperatures. Where another number is used below a line it represents the condition as changed for the last five days.

The following table, Figure 12, shows dividing lines between plants injured and not injured by *Fusarium* because of heat and soakage.

10% 65° / 10% 65° —	20% 65° / 20% 65° —	20% 65° / 30% 65° —	20% 65° / 40% 65° +
10% 80° / 10% 80° —	20% 80° / 20% 80° +	20% 80° / 30% 80° +	20% 80° / 40 80° +
10% 50° / 10% 95° —	20% 50° / 20% 95° —	20% 50° / 30% 95° +	30% 50° / 40% 95° +
10% 65° / 10% 95° —	20% 65° / 20% 95° +	20% 65° / 30% 95° +	30% 65° / 40% 95° +
10% 80° / 10% 95° —	20% 80° / 20% 95° +	20% 80° / 30% 95° +	30% 80° / 40% 95° +
10% 50° / 10% 50° —	Flooded Twice 50° +	Flooded Once 50° +	20% 50° / 20% 50° —

Figure 12.—Giving summary of greenhouse studies of potato health. Percentages of water in soil and temperatures of soil for first seventy-five days shown above the line, and for the next five days shown below the line in the form of a fraction in each case. Presence of disease is shown by a plus (+) sign. Absence of disease is shown by a minus (–) sign. Note that the combination of adverse factors governing the appearance of *Fusarium* in the ducts is limited by the solid lines drawn through the table. As the water was applied to the surface, the distribution of the water was not quite uniform throughout the soil, and it is therefore believed that a line somewhere near the position of the dotted line would more accurately represent the boundary.

It would be desirable to repeat this experiment in summer, in dry air and sunshine, out of doors. There would be likelihood of producing the leaf-roll disease in typical form in some of the conditions and entirely healthy plants in others.

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Every warm summer, in the corn belt, potato leaves roll as they did in the epidemic of leaf-roll in Colorado, but they usually recover to a large extent, with good fall weather. For many years, in the Greeley district, if leaves were once rolled by long continued heat and heavy soil and heat, or watering in hot weather, all chances for a real good crop were considered to be past. There is a strong probability that it is the fungus factor that makes the leaf-roll condition permanent. It seems to be the sum of poor nutrition, a starvation matter, due to root injury.

THE INFLUENCE OF SOIL HEAT AND WARM AIR.

On April 8th, the plants in one cross row were transferred from each of the other cabinets to the 95° cabinet, and part of them were covered with a glass case, heated by two 32 c. p. carbon lamps to

Figure 13.—A case in which summer air temperatures were produced by heating with large electric globes. The temperature of the air proved to be a comparatively unimportant factor of potato health.

an average temperature of 90° (ranging from 75° at night to 110° in the sun) and well ventilated, to simulate summer heated air. We give the detailed records with the cuts and in the table. (See Figure 13.)

Those plants which had been wet and warm were almost instantly wilted by transferance to the 95° cabinet. Those that had been dry or cool stood up much longer. The addition of heated air in the glass case made very little difference to the plant troubles or in the time of going down from the soil heat.

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IV. FIELD STUDIES OF HEAT AND SOAKAGE AND OTHER FIELD OBSERVATIONS.

Through the co-operation of the Board of Commissioners of Rio Grande county, who furnished the equipment, and of Mr. R. A. Chisholm, who cared for the work and took the yields, a field experiment to determine the best level of water for the sub-irrigation of potatoes was performed during the season of 1912 at Del Norte in a mellow, sandy loam soil.

Four watertight galvanized iron tanks, four feet long, four feet deep and two feet wide (Figure 14) were set in the ground flush with the surface. In a corner of each a five-foot piece of corrugated galvanized iron eavestrough piping was placed upright, the lower end being notched and placed on the bottom of the tank. To

Figure 14.—Setting tanks for the study of the best water level for the sub-irrigation of potatoes.

prevent clogging, the bottoms of the pipes were surrounded with a little pile of good-sized pebbles. Then the tanks were filled with earth, and Pearls were planted in each.

A record of rainfall was kept, and deficiencies from an average rainfall were made up by sprinkling a calculated amount of water upon the top of each tank. Additional water was run down the pipes, through which, also, the water levels were measured so

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that the ground water level was kept at one foot from the surface of the soil in one tank and at two feet, three feet and four feet for others. Numbering the tanks according to the distance to water, the results were as follows:

YIELDS FROM SUB-IRRIGATION TANKS.

Tanks	Nos.	Total Weights of Tubers	No. of Large Tubers	No. of Culls	Quality
1	4	3.5 lbs.	13	23	Very poor
2	3	6.0 lbs.	12	8	Poor
3	3	9.0 lbs.	17	8	Fine
4	2	6.5 lbs.	12	18	Good

It was regrettable that an even number of hills were not secured for comparison, but it was very evident to the observer that, for the fine, mellow garden loam used, three feet deep is the proper level for the irrigation water where subbing is practiced. The leaves of the plants in No. 1 and No. 2 were badly rolled, and the potatoes inferior. In No. 3 the tubers were larger, few were small and the total weight of tubers fit for table use was most in the aggregate and per hill. No. 4 showed signs of drouth and did not make as many of its tubers of desirable size as an average plant should produce.

It is the keen desire of many thoughtful men that eventually the sub-irrigation system may be eliminated. It is calculated that row irrigation will take less water per acre and that the drainage system that should be installed with a new system of irrigation will make it possible to use the water several times, and largely increase the acreage that can be planted, and the prosperity and future security of the agriculture empire, which lies west of the magnificent Sangre de Christo range.

At Greeley, in 1912, in co-operation with Mr. E. R. Bliss, two experiments were performed in studying the conditions necessary for potato health. One small patch of ground was shaded by a

Figure 15.--Shading the ground did not do much good in 1912.

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canopy (Figure 15) and soil temperature records kept, but it was found that the shaded plants were but little, if any, better than the average. It was true of 1912 in general that conditions of temperature were good, but that the crop was almost as badly affected by leaf-roll as in 1911.

A large cold frame (Figure 16) was placed over another small patch of hills with the idea that the additional heat might make the disease worse. Soil and air temperatures were higher but the light

Figure 16.—Trying to hold some field plants still warmer by covering them with a large cold frame. The results were not what was expected.

was more subdued and evaporation, and undoubtedly transpiration. were less. The plants, much to our surprise, were rather better than elsewhere in the field, and did quite a little growing late in the season, after other plants were done.

The effect of cultivation upon soil temperature is not to be overlooked. The heat rays pass through the air and warm it hardly at all. The air is heatetd, by radiation, from the surface of the earth which absorbs the sun's rays. If the surface of a potato field is loose and dry it may be very hot, but comparatively little heat goes deep into the earth, and when the sun has set, the earth and air above cool quickly. This is the condition in a desert, where the surface is loose sand, and this should be the condition in a potato field in a region of intense sunshine. Every barefoot boy knows how much hotter road dust is than solid earth. The road dust is letting less heat down into the soil, is hotter itself, and for the time being is giving off more heat by radiation.

For three years we carried a pocket thermometer for the observation of the temperature of soil and water. Under a bright sun,

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very high surface temperatures have been observed. At Briggsdale, on July 16, 1912, in a patch of potatoes in a garden we found a surface temperature of 133° (It has reached 142° in the writer's garden at Ames, Iowa), while at four inches the temperature was 81°. The surface temperature in the shade of a potato plant was 93°, on the center of a hill 80°, and four inches deep, 74°. Sandy road dust was 130°, and the side of an ant hill was 135°, and level coal dust was 134°.

Because the Greeley district slopes to the sun, slightly more heat per square foot is absorbed than would otherwise be the case. At Ault, on July 13, 1912, at noon, road dust piled on a newspaper in the full sun was 130° on the side facing the sun and 123° on the side sloping away from the sun. That afternoon at 1:30 in a crusted potato field near the pea huller, the temperature was 110°, at three-fourths of an inch below the surface, and at five inches, 84°, which are dangerous temperatures for potatoes. At the same time, in a well cultivated beet field, the top soil was 115° and at five inches the instrument read 78°.

At 3 p. m. on June 22, 1912, on the Rasmussen Brothers' farm five miles east of Greeley, in a crusted potato field, the temperature at the seed pieces was 89°. In a portion of the field cultivated the night before the temperature at the seed pieces was 75° and in rows cultivated that morning, 72°. Driving out the next morning to the same place at sunrise, the temperatures at seed pieces were found to run about 67°, at eight inches deep 70°, and at fifteen inches 70°. The air at 5 o'clock, five feet from the ground, registered 54°. As the sun came up, shallow temperature changed almost instantly. In the sun at 5:30 surface soil temperatures were 70°, in the shade of a row 62°, in a horse track 57°. Mr. Charles Rasmussen suggested the use of a beet cultivator to break the crust without destroying the planter ridge.

The above temperatures are typical of hundreds taken. The eight to ten inch cultivation, which is the universal practice of potato growers in the Greeley district, is needed to hold the soil open for protection against the effect of heavy rains, and to make a good ditch possible. but we are fully persuaded that it is necessary, also, to influence deeper rooting early in the season and to provide a very deep, porous blanket against the entrance of heat.

In 1914, Mr. E. E. Isaac, a graduate student, working under the author's advice, found that at Ames, Iowa, in less intense sunshine and with less thorough cultivation than is practiced at Greeley, deep cultivation (6 to 7 inches) as compared to shallow cultivation (3 inches) made the soil at a depth of the seed piece, on the average,

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between two and three degrees cooler in the warmest part of the day. On extremely hot days the saving at the high point was sometimes as much as 7°. The deeper rooting would be a factor also in favor of deep cultivation, as the deeper the roots the less their temperature at the top heat of the day. With heavy soils, the poorer aeration of the roots at several inches below the surface would be an adverse factor, but potatoes should not be planted on such soils in regions of high soil temperatures.

The temperature of irrigation water is an important factor, also, because water holds from seven to eight times as much heat as good potato soils, so that the temperature of such a soil is profoundly influenced by the temperature of the irrigation water. Water coming a long way in small ditches is considerably warmed. A return to the planting of trees on ditch banks would have some excellent results. To mention an extreme case of warm irrigation water, we found near the lower end of one of the ditches out of the Poudre, one afternoon in July, 1912, a potato field being irrigated with water which was reaching the lower end of the field at 108°. At Glenwood Springs, in the same month, we found the Grand river at about 52°, and the Roaring Fork water going into the potato rows from the snows of Mount Sopris at 54°.

V. HISTORY OF POTATO-GROWING DISTRICTS.

As our fathers have cleared new forests, moved west to new prairie lands, or brought into cultivation by their labor and engineering skill the new and wonderfully fertile irrigated districts of the West, they and we have had for almost three hundred years new lands on which to grow potatoes. Virgin soils produce well nourished, well rounded tubers from healthy plants. As virgin soils are no longer available, we shall be obliged to consider with care the soil requirements for the health of potatoes. As time goes on, our loose, sandy soils, sometimes held in little respect, will be better fertilized and more appreciated because of their healthfulness for potatoes.

At the Colorado station, no question came more often to the potato specialist than: "Why cannot we grow potatoes? We did here in the early days, but we cannot now." Only recently an Iowa man who had bought land near Denver sent the same question to Iowa State College. This question came very often from the vicinity of Rocky Ford, from Canon City, from Pueblo, from Rye, from the Fountain Valley below Colorado Springs, from Golden and Denver, Longmont, Stove Prairie and Virginia Dale. The

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Arkansas divide once shipped potatoes by the trainload. The crop failed, as did likewise an attempt by the Colorado station to grow potatoes at Elizabeth, under improved methods, in 1909. This crop was harvested by the writer.

On Clear Creek and Bear Creek near Denver, in 1863 or 1864, according to Mr. Asa Sterling, of Greeley, one crop of potatoes, of excellent quality, was raised but none have been raised since.

On the present site of Denver, in the suburban region west of Denver University, potatoes were raised in the early days and of good quality. On August 10, 1912, we visited the locality, talked with gardeners and small farmers and saw the brick residence, spacious for its time, of the man who was known as "Potato Clark," because of his great success at that place with potatoes grown for Denver and the mining camps, in the early days. We later had a gracious letter from his widow, an elderly lady in the East. All were agreed that potatoes had failed about 1876 and, though often tried, they have not been grown thereabouts with any success whatever for forty years.

The same was true later, but in less degree, of the farms about Longmont, Johnstown and Fort Collins, on soils so rich that they grow the largest yields of sugar beets and grain produced anywhere.

The plants, in such of these cases as have been observed, appeared to have the leaf-roll disease. On the station plots at Fort Collins Professor E. R. Bennett, in the years 1907 to 1912, secured about one fairly healthy crop in the six.

Down the Platte river, at Brush, and at Julesburg, where the yields were formerly very large, failures came sooner than on less rich soils. In 1915 crops of potatoes have been good again, the Greeley district having one of the best crops it ever raised. The worst crop was in 1911, but the crops of 1912, 1913, and 1914 were far below the average.

On the West Slope there are heavy lands which have gone out of potato production—mostly bottom lands that have had the leaf-roll. Other bottom lands and damp spots at the breaks between benches, will have trouble, but the high sloping mesas, with their pure, cold water, have fine conditions for permanent potato production.

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THE EVIDENCE OF A FUNGUS OR INFECTION FACTOR IN LEAF-ROLL DISEASE IN COLORADO.

First.—The two regions which had the disease the most severely are tied together by one of them securing the major portion of its seed from the other.

Second.—In the Greeley district, in 1911, the soil heat would lead us to expect trouble, but the weather conditions in 1912 were ideal. In that year the United States grew the largest crop of potatoes that it ever grew and had the largest yield per acre since the Government has made estimates of yields. Nevertheless, the crop in the Greeley district was very little better than in 1911, in spite of new seed, and much change in crop rotation. Some active factor of infection must have been carried over in the soil, and must have been distributed universally over the district by wind, water, tools and potato storage.

Third.—With decreased acreage of potatoes for 1912, 1913 and 1914, and a season in 1915 showing a large deficiency in temperature (according to the September report of the Denver branch of the Weather Bureau) for May, June, July and August, and some deficiency for September, but no better a season than 1912 and with change of soil and seed as in 1912, the Greeley district has a record crop on a small acreage. Some hidden injurious factor has been lessened.

Irrigation water affords a ready means for the distribution of any microscopic life, and I am indebted to Dr. L. R. Jones, of the University of Wisconsin, for his opinion that *Fusarium* might be distributed by the wind.

In Iowa, conditions which potatoes have to meet are much the same as in the Greeley district. We have less soakage, but we have large areas requiring artificial drainage and much soil which is heavier than that at Greeley. We have more heat. We have no district that has for a long time specialized, with success, in potatoes. No less than five districts that once grew many potatoes are producing less, and some none, for shipment, and in all such districts poorer shape and yields have been reasons for reduction of acreage. We have one area of deep, sandy loam, naturally drained, that promises to produce many potatoes permanently. We have another very large area of deep, loess soil, naturally drained, where potatoes do well. We have no large area on tile-drained soil where potatoes are a reliable crop.

We may regard it as an axiom that where seed potatoes cannot be maintained for some years conditions for potato health are not the

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best, and that where seed potatoes can be maintained for years, conditions are good. The author has found the following instances of permanency and health in a State most of whose area finds it desirable to send away for seed:

Mr. W. C. Boyce, Winterset, Iowa, has maintained Bonanza potatoes on the same farm for 29 years. His farm is very large. He raised but five to ten acres of potatoes on portions of the farm that are extra well drained.

At West, Iowa, Anton Neuman, potato man for one village of the Amana colony, has maintained Snowflakes for 37 years. He has deep, mellow, sandy loam. There are no other potatoes than his raised or used for a distance about the village.

At Tabor, close to the Missouri line, Mr. Ed. L. Gladwin has maintained the same stock of Vick's Champion potatoes for 27 years. His soil is deep, self-draining loess and he raises but one or two acres on a considerable farm.

At Auxvasse, in central Missouri, Mr. I. J. Attemron maintained Early Rose for 31 years and then lost seed accidentally.

The soil and climatic conditions for health of cabbage are very much the same as for potatoes. The Amana society has grown cabbage as one among a full line of vegetables, on sandy loam in Iowa county for 60 years without serious disease. In the second county east, in a specialized cabbage district, cabbages cannot be grown safely more than one year on the same ground. Often

Figure 17.—The health needs of cabbage are much like those of potatoes. Among cabbages are found plants which do not have the yellows or *Fusarium* disease. Their progeny is for the most part resistant also. In the center is shown on sick ground healthy cabbages which produced 20 tons per acre, where plants from other seed, on right, were all sick.

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whole crops are destroyed by the yellows, a *Fusarium* disease, and the lands stay sick to cabbage for an unknown number of years.

VI. THE HOPE OF DISEASE-RESISTANT POTATOES.

Among cabbages there are found a few that do not have the disease and their seed produces plants most of which do not have the disease, as the author has shown in Muscatine county, following the work of Dr. L. R. Jones, in the Racine district of Wisconsin. To have an equal chance of finding such plants among potatoes, a vast number of seedlings would have to be produced, and in the Greeley district practically no seed is borne except by the Pearl bastard. If, among many hundreds of thousands of its seedlings, a goodly number of resistant plants were found, it might be possible to find one worthy to use as the commercial variety of the district, but all these seedlings and all the seed stock of any worthy variety would have to be produced elsewhere under better conditions for health and then be brought to the regions of greater strain upon health in potatoes. The price of a small battleship would be required to carry on breeding work on a scale vast enough to promise success under such difficulties.

VII. SUMMARY.

Leaf-roll, regarded as the sum of ill health for potatoes in Colorado, appeared widely and suddenly in 1911, continued in 1912, 1913 and 1914, and disappeared in 1915.

Soils in the Great Plains region may reach dangerous temperatures in years of more than average sunshine. Potatoes were found badly injured in good, but overheated, potato soils, but heated air, constantly changed, seemed to add very little to the ill health of the plants.

In 1911, temperatures for the critical month of June, for the whole upper foot of soil, averaged, in the locality most affected, 10° more than in June, 1910. In other regions there was much injury from over soakage of potato lands.

Potato roots use as much as four feet of suitable soil, but do not enter very close-grained soils, and die in wet soils. The potato root cap offers additional evidence that potato roots have the power neither to enter nor to live in close-grained, easily wet, and poorly aerated soils. The structure of the potato leaf and practical observations indicate that a damp atmosphere is best for potatoes.

Potato plants grown under controlled soil temperatures and percentages of moisture gave evidence that soil heat and soakage

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(causing lack of aeration) are joint factors adverse to health of potato roots and plants. These factors were in direct relation to the presence or absence of *Fusarium* hyphae in the water tubes. Irrigation practice and experience also prove that heat and soakage are adverse factors that should not be combined.

Field studies of sub-irrigation indicated, in a certain sandy loam, that three feet was the best depth to water, and that a higher water level was injurious and a lower level insufficient.

Indifferent results were secured by shading and by covering plots of potatoes with glass.

Deep cultivation is approved by practice, by field observations and by experiment as a means of protecting potato roots from extreme temperatures.

The temperature of irrigation water varies widely, and is an important factor because of its high specific heat as compared to that of potato soils. Cold, pure water is best for potatoes.

We have had new ground for potatoes in settling up a new country and a new State. Many districts have become quickly unable to grow potatoes at all, the heavier soils in warmer regions going out first.

There has been conclusive evidence, in-the-large, that the leaf-roll in Colorado, in addition to heat and soakage, had an infectious or fungous factor.

Cabbage plants, resistant to similar conditions, are readily secured thru selection and their culture is successful in a commercial way on "sick" land. No resistant plants among potatoes were seen. Only a few sorts of potatoes are grown, and hundreds of thousands of seedlings would be necessary for the selection of resistant plants. Almost no pollen was found except on the Pearl bastard, under leaf-roll conditions.

Seedlings, when secured, could not be developed successfully under leaf-roll conditions.

General Summary.—In potato health, soakage, close-grained soils and poor aeration of soils give the same results. *Soil heat, poor aeration,* and *infection* are the three factors adverse to health in potatoes. The less a district has of one adverse factor, the more it can stand the other two. The more open and cool a soil, the better it is adapted to potatoes; the heavier, damper and warmer a soil is, the poorer is it adapted to potatoes and the quicker will the crop fail.

Regions having fair conditions for health of potatoes can only hope to grow their crop permanently by planting a very small proportion of the area in this crop each year.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A STUDY OF COLORADO WHEAT

BY W. P. HEADDEN

Part II

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
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The Agricultural Experiment Station

FORT COLLINS, COLORADO

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A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART II

In Part I of this study (Bulletin 208) we gave the results obtained during the season of 1913 in a study to determine the moisture in the soil, the variations of the nitric nitrogen in the soil, the various nitrogen compounds in the plants from the time of bloom till the wheat was ripe, and also the ash constituents of the plants.

The nitric nitrogen in the plants was not given because we wished to repeat our work on this subject. Our results were not concordant, neither did they agree with such data on the subject as I was able to find. Jost, in his Lectures on Plant Physiology, makes the statement that the air-dried plant may contain from 1.8 to upwards of 2.0 percent of nitric nitrogen, but says nothing about its occurrence in the green plant. He does not say whether it always occurs or not; the impression made by his language is that it may or may not be present. The quantities given are so far in excess of anything that we found, that we deferred any consideration of the subject at that time.

The ash constituents of the plants were given for some samples taken in 1913 and of one series taken in 1914. This last series was taken when the plants were entirely ripe and were really straw; the other samples were much less mature. This difference in the development of the plants at the time that they were cut lessens, in some degree, the value of the results for the purposes of comparison, but does not detract from their value in showing the effects of the fertilizers applied to the different plots upon the mineral constituents of the ash.

The purpose of this preliminary work has been stated to be the finding out of the distinguishing character of Colorado wheat, if it has any, and to ascertain if possible those factors in our conditions which determine this character.

With this purpose in view, and to establish what the effects of

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the individual fertilizers are, we studied the composition of the plants from the time of blooming till they were mature. This was done to enable us to draw sume inferences, at least, in regard to the part played by the soil constituents as distinguished from the climatic conditions. We hoped by applying nitrogen, phosphorus and potassium separately and each in varied quantities, to so increase the characteristic effects of each, that it would enable us to recognize their specific effects, not merely upon the composition of the plant, but also upon the characteristics of the grain. This procedure was based upon the assumption that the land used in our experiments already contained these elements in sufficient amounts, and in such relative quantities, that it would produce wheat which would be entirely normal for our locality, and that by adding sufficiently large quantities of these individual substances in proper form, we would be enabled to recognize their respective influences upon the grain, and particularly upon the bread-making qualities of the flour. While the composition of the flour, especially in respect to what we may designate its minor details, may have less effect upon the quality of the flour than we think, it is certainly wise in this case to be as thorough as possible, even if our effort produces but few usable results. I have in mind that it is customary to consider the amount of nitrogen in a wheat as indicative of its merit for making flour, assuming at the same time that all other constituents are either present in sufficient quantities, or are of so much less importance that mention of them is not called for. It is not intended to state that the importance of phosphorus or other ash constituents are never considered, for this is not true, but that the importance atached to the amount of nitrogen contained in the wheat overshadows that of the other constituents. Our general judgment is that the higher the nitrogen, the better the flour that it will yield, that is, the greater will be the amount of gluten contained. In this general view, only the total amount of nitrogenous substances is considered; neither the quality of these substances, gluten, nor the presence of other substances which, in the end, may have a deciding influence upon the quality of the flour, is given any weight. There is a large mass of literature upon this subject, but there are not any fixed criteria which may be used in judging the value of flour, nor is there any agreement as to the causes of the differences found in flours or wheats grown in the same, or in different places.

The portion of this work already published (Bulletin 208) shows that the nitrogen supply in the form of nitrates in the soil affects the amount of the total and also that of the proteid nitrogen in the plant throughout the period between blossoming and maturity.

The ammonic and amid nitrogen found in the plants probably

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represent nitrogenous compounds in a transition stage, at least to a large extent; still it is true that we find these more abundant in plants grown with the application of nitrates than in others. We further found that the effect of phosphorus, and also that of potassium, upon the total nitrogen in the stems, leaves, and heads was very small, until the period of ripening approached, when these elements seemed to effect an increase of the total nitrogen in the heads, but the proteid nitrogen in the heads of wheat plants dressed with phosphates or potassium salts was not greater than in those of plants that had received no fertilizer.

The mineral constituents of the plant were also affected by the application of the nitrate, but not in a uniform manner, some constituents increased while others were depressed. Calcium, magnesium and potassium (sodium is included) were increased, silicon was decidedly depressed, but the phosphorus in the plant did not seem to be affected. This statement pertains only to the plant and is not to be applied to the grain, which will be discussed later.

The effect of the application of water at different times was not studied, except by the results obtained on one plot which received a total application of two feet of water, one applied 12 June and the other 12 July, 1913. Four plots were irrigated on these dates, but plants from only one of these were analyzed. The effect of this increased water supply upon the amount of total and proteid nitrogen in the stems, leaves and heads of the plants was not marked enough to justify, in any measure at all, a statement that any results had been produced. The same statement applies to the yield of both total dry-matter and of grain, for in none of the four experiments was there an increase in either respect. The application of one acre-foot of water on 12 June, when the wheat was in boot, was sufficient for the production of a maximum crop.

The soil moisture for the season of 1913 is given in detail in Part I (Bulletin 208 of this Station).

It will be recalled that in the plan of these experiments every fourth plot was a check. The above statements are all based upon a comparison of results obtained with plants from these check plots with those obtained with plants from the plots to which we applied fertilizers.

It was impossible for us, during the season of 1914, to carry out the plan pursued in 1913, so we were not able to repeat the observations of 1913 till the season of 1915.

OBSERVATIONS ON SOIL MOISTURE, COMPOSITION OF THE PLANT, AND NITRIC NITROGEN IN 1915

The weather conditions in 1913 were favorable for our experiments, but were scarcely more so than they usually are. We would say that it was a good year, perhaps a little more favorable than an

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average one, but not enough so to cause comment. This was not the case with the season of 1915, which the consensus of opinion would unhesitatingly designate as a bad year for wheat, a wholly abnormal year. Mr. Robert Trimble, in charge of our meteorological observations, has furnished me the data for the months of April, May, June, July and August of the respective years, which show the differences between the seasons in so far as may be done by figures. The total rainfall during these months in 1913 was 6.77 inches, and in 1915, 13.37 inches. In 1913 we had only four wholly cloudy days during these months, while in 1915 we had only 57 days free enough from clouds to justify the designation of clear. In the following statements of mean temperatures that for 1913 is given first, and then that for 1915. April, 46.1°, 50.05°; May, 54.8°, 50.35°; June, 63.2°, 59.62°; July, 66.8°, 64.74°; August, 69.8°, 62.77°. The rainfall in 1915 was not only unusual, but it was distributed through the season so that the plants were kept wet most of the time, the prevalent cloudiness preventing a thorough external drying, even when there was no actual rainfall.

This proved to be very prejudicial, not only to my crop, but locally to all of our spring wheat, especially to our popular variety, the Defiance, because of the severe attack of rust which was induced by these conditions.

In 1913 I applied to my plots one acre-foot of water on 12 June and to four of them a second acre-foot on 12 July. Thirty-two of the plots received, as irrigating water and rainfall, practically 19 inches of water during the growing season, 12 inches of which was applied at one time and in clear weather. Three and one-half inches of the 6.8 inches of rain fell in April and May, and 2.5 inches between 13 and 24 July. This last period of rainfall caused some rust to develop. The subsequent fourteen days were dry and bright, and the damage was not serious. In 1915 the plots received from 0.5 to 0.6 of an acre-foot of irrigation water, this being all that was required to flood the land. It will be noticed that the amount of water received during the two seasons was very nearly the same. In 1915 the amount of rainfall was not only greater, but its distribution was different and accompanied by a great deal of cloudiness. These conditions affected not only the rate of the development of the plants and of the rust, but modified our conditions of soil moisture, the distribution of the nitrates, and probably also affected their formation, as well as the amount of fixation that took place. These last two factors are, unfortunately, not definitely known nor are they easily ascertained.

The general conditions as here described may seem to be unfortunate. As matters stand they really are, but were it not for the introduction of the factor of rust, I would be inclined to consider it

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fortunate that our experiments were made during this season, for many facts, to be given subsequently, will tend to show, or perhaps prove, that the amount of water applied, be it as rainfall or irrigation, has comparatively little influence upon the composition of wheat.

It is very fortunate in this connection that we made three parallel series of experiments with three different varieties which differ in their susceptibility to injury by rust. If this had not been the case, if we had used only the Defiance in these experiments, we would not have been satisfied to abide by any results obtained. This variety was so badly shrunken that I could not sell it, except for chicken feed. The weight per bushel and the yield will indicate how badly it was injured, almost wholly, as I think, by the rust. The grain weighed from 47 to 53 pounds per bushel and the yield ranged from 10 to 23 bushels per acre. The other varieties were much better, both in weight per bushel and in yield per acre, though they also suffered from the effects of rust to some extent. The maximum yield, 41.5 bushels, weight per bushel 60 pounds, was obtained with Kubanka.

It may be well to state, in this connection, that the plants grown with the application of sodic nitrate seem more easily atacked by rust than those which are grown without it, and on this account tend to produce shrunken wheat. This, however, seems to be a specific effect of nitrates upon the wheat kernel as well as an effect of rust. This year the two acted together and produced, in the case of the Defiance, an almost total failure of the crop. This statement is made in this connection lest it should be thought that subsequent statements, pertaining to the effects of nitrates, did not make sufficient allowance for the effects of this parasite.

MOISTURE AND NITRIC NITROGEN IN THE SOIL, 1915

During this season, 1915, we took no samples to a greater depth than four feet, whereas in 1913 we took four series of samples to a depth of twelve feet. In 1913 we took 42 series in fallow and 18 series in cropped land to a depth of four feet. In 1915 we took 54 series in cropped and 6 series in fallow land to the depth of four feet. The moisture and nitric nitrogen were determined in all of these samples and the total nitrogen in twenty of the series. The dates on which our samples of 1915 were taken do not follow at regular intervals because of the frequent rains. We endeavored to allow a few days to elapse after a rain before we took the samples, but even with this precaution it is not probable that we have succeeded in making the samples altogether comparable with those of 1913.

The results obtained are given in the following tabular statements:

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MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 13 MAY, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen, Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	14.08	4.57	14.60	1.05	14.08	4.57	12.76	4.34
4 to 7 inches	17.74	4.30	17.50	0.93	17.74	4.30	16.49	4.41
8 to 12 inches	17.73	6.42	17.41	3.12	17.73	6.42	17.04	5.44
13 to 24 inches	17.00	5.86	16.78	6.01	17.00	5.86	16.97	10.04
25 to 36 inches	16.48	4.80	16.87	1.50	16.48	4.80	16.92	3.80
37 to 48 inches	15.74	2.84	16.35	1.66	15.74	2.84	16.32	1.74
Kubanka Plots—								
Top 3 inches			12.07	4.19	12.53	4.21	13.93	5.08
4 to 7 inches			16.81	4.01	17.17	4.44	17.38	5.30
8 to 12 inches			16.85	6.52	16.99	5.69	16.72	4.42
13 to 24 inches			15.85	9.66	16.67	7.34	16.91	7.77
25 to 36 inches			16.10	5.22	16.54	4.41	16.51	5.24
37 to 48 inches			16.77	2.75	17.07	2.76	16.28	2.32

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 18 JUNE, 1915

Red Fife Plots—								
Top 3 inches	13.32	5.45	9.08	1.80	9.20	1.45	8.33	1.21
4 to 7 inches	17.44	4.46	12.82	1.27	12.76	1.19	12.52	0.79
8 to 12 inches	16.61	2.50	13.45	1.49	12.93	1.01	14.11	0.89
13 to 24 inches	16.77	2.00	14.27	1.22	14.74	0.65	13.67	0.80
25 to 36 inches	16.57	4.24	14.32	0.97	14.59	1.47	13.99	0.80
37 to 48 inches	16.05	3.64	14.75	0.97	13.97	1.38	14.65	0.81
Kubanka Plots—								
Top 3 inches			10.45	2.56	10.20	1.39	10.59	1.55
4 to 7 inches			14.14	1.38	13.71	1.37	13.60	1.60
8 to 12 inches			13.63	1.21	13.52	1.45	13.97	1.61
13 to 24 inches			13.72	1.21	13.79	0.80	13.83	1.53
25 to 36 inches			14.52	3.66	14.08	1.46	13.70	3.54
37 to 48 inches			16.15	2.15	14.65	1.38	13.85	1.92

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MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 8 JULY, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	12.93	6.86	14.13	1.54	14.60	1.05	14.51	1.30
4 to 7 inches	17.48	3.36	14.95	1.31	15.56	0.82	15.89	1.40
8 to 12 inches	17.48	3.36	15.40	1.76	15.82	1.40	15.81	1.65
13 to 24 inches	16.97	1.92	15.30	1.02	16.04	1.16	15.27	1.63
25 to 36 inches	16.64	2.25	15.27	0.82	15.74	0.90	14.33	0.98
37 to 48 inches	16.07	2.56	14.20	0.81	15.80	0.82	15.04	0.49
Kubanka Plots—								
Top 3 inches			13.23	1.20	15.46	0.74	14.61	0.77
4 to 7 inches			15.02	0.81	16.06	1.07	16.17	1.16
8 to 12 inches			14.48	1.22	16.01	0.91	16.55	1.33
13 to 24 inches			14.80	0.81	15.73	0.66	16.30	0.83
25 to 36 inches			15.44	0.41	15.96	0.33	15.96	0.66
37 to 48 inches			16.62	0.16	16.18	0.25	17.19	0.42

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 3 AUGUST, 1915

Red Fife Plots—								
Top 3 inches	11.37	8.66	12.47	1.58	12.31	0.71	12.09	1.25
4 to 7 inches	15.65	5.89	12.14	1.11	11.56	1.88	12.06	0.83
8 to 12 inches	16.06	4.72	11.11	1.29	11.21	1.02	11.18	0.86
13 to 24 inches	16.06	2.11	10.75	0.85	12.13	1.22	11.96	0.78
25 to 36 inches	15.38	1.72	12.32	0.95	12.75	0.79	12.72	0.56
37 to 48 inches	15.44	1.93	12.97	0.69	13.18	0.69	12.96	0.00
Kubanka Plots—								
Top 3 inches			11.83	0.98	12.59	0.79	12.83	0.64
4 to 7 inches			11.23	0.86	12.51	1.11	12.40	0.47
8 to 12 inches			10.28	0.85	11.45	0.55	11.87	0.47
13 to 24 inches			10.03	0.54	11.59	0.55	12.19	0.55
25 to 36 inches			11.44	0.31	12.46	0.39	12.98	0.40
37 to 48 inches			13.97	0.06	13.69	0.49	13.68	0.16

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MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 30 AUGUST, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	9.14	2.15	12.30	2.22	11.98	2.44	12.74	2.87
4 to 7 inches	12.64	1.59	12.16	1.82	12.76	1.75	13.65	2.41
8 to 12 inches	12.68	1.91	10.85	1.25	10.72	1.40	11.05	1.41
13 to 24 inches	14.18	1.54	10.78	1.71	10.81	1.01	11.45	0.78
25 to 36 inches	13.95	0.73	12.36	0.48	12.16	0.87	12.24	0.23
37 to 48 inches	14.16	2.19	12.88	0.24	12.71	0.64	12.62	0.32
Kubanka Plots—								
Top 3 inches			10.62	2.18	10.22	2.09	12.21	2.45
4 to 7 inches			12.04	1.50	13.68	1.49	14.28	2.11
8 to 12 inches			10.18	1.47	10.91	1.17	11.58	1.57
13 to 24 inches			9.62	0.84	10.89	1.25	12.03	0.94
25 to 36 inches			11.29	0.86	11.71	0.78	13.06	0.96
37 to 48 inches			12.85	0.64	12.56	0.72	13.64	0.80

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 14 SEPTEMBER, 1915

Red Fife Plots—								
Top 3 inches	10.08	4.79	12.60	5.70	11.62	3.85	11.90	5.76
4 to 7 inches	12.54	2.62	13.22	3.11	12.75	3.02	13.56	3.45
8 to 12 inches	13.40	3.29	12.01	2.05	11.09	1.95	12.01	2.21
13 to 24 inches	13.99	2.02	11.26	1.17	11.25	1.41	12.08	1.50
25 to 36 inches	13.81	1.93	12.28	0.87	12.32	0.95	12.41	1.03
37 to 48 inches	13.63	1.85	12.93	0.87	12.30	0.87	15.75	0.82
Kubanka Plots—								
Top 3 inches			10.38	3.25	12.47	2.78	12.68	4.85
4 to 7 inches			12.93	1.59	14.18	2.02	15.10	2.53
8 to 12 inches			11.30	1.25	12.08	1.26	12.44	1.27
13 to 24 inches			10.81	0.70	11.09	0.47	11.98	1.10
25 to 36 inches			12.74	0.24	12.17	0.39	12.93	0.78
37 to 48 inches			14.38	0.00	13.43	0.16	13.31	0.40

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MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 28 SEPTEMBER, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	16.86	2.50	17.91	2.96	17.90	2.54	17.75	3.38
4 to 7 inches	15.91	5.70	16.40	4.65	16.84	4.76	16.96	6.69
8 to 12 inches	13.37	1.60	12.93	1.75	12.39	1.98	11.62	1.73
13 to 24 inches	14.14	1.21	11.30	0.78	11.53	0.78	11.14	0.86
25 to 36 inches	14.08	1.13	12.50	0.56	12.29	0.47	11.20	0.39
37 to 48 inches	13.52	1.60	12.77	0.24	13.11	0.24	11.32	0.00
Kubanka Plots—								
Top 3 inches			15.98	3.80	16.91	3.25	17.17	3.44
4 to 7 inches			16.00	4.30	15.99	4.05	16.77	4.59
8 to 12 inches			11.38	1.80	13.36	1.92	14.45	1.95
13 to 24 inches			10.92	0.78	11.69	0.71	13.07	0.48
25 to 36 inches			12.88	0.40	12.56	0.40	13.53	0.48
37 to 48 inches			14.36	0.32	13.43	0.32	13.87	0.08

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 25 OCTOBER, 1915

Red Fife Plots—							
Top 3 inches	No separate samples	14.82	2.09	15.16	1.80	14.84	3.34
4 to 7 inches	taken, same as	17.05	2.26	17.43	1.93	17.08	5.03
8 to 12 inches	Section 1800	16.72	2.88	16.88	3.51	16.72	3.84
13 to 24 inches		16.05	1.90	16.25	2.16	16.51	2.99
25 to 36 inches		15.12	0.41	14.92	0.98	14.36	0.81
37 to 48 inches		13.78	0.32	13.56	0.56	13.19	0.64
Kubanka Plots—							
Top 3 inches		13.68	2.26	14.88	1.71	14.67	1.71
4 to 7 inches		16.98	3.01	17.37	1.85	17.16	1.51
8 to 12 inches		16.39	3.82	17.35	2.60	16.91	2.50
13 to 24 inches		15.72	1.73	16.38	2.08	16.66	1.92
25 to 36 inches		14.65	0.57	15.49	0.58	15.51	0.50
37 to 48 inches		15.06	0.49	14.48	0.57	14.64	0.25

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MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 30 AUGUST, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	9.14	2.15	12.30	2.22	11.98	2.44	12.74	2.87
4 to 7 inches	12.64	1.59	12.16	1.82	12.76	1.75	13.65	2.41
8 to 12 inches	12.68	1.91	10.85	1.25	10.72	1.40	11.05	1.41
13 to 24 inches	14.18	1.54	10.78	1.71	10.81	1.01	11.45	0.78
25 to 36 inches	13.95	0.73	12.36	0.48	12.16	0.87	12.24	0.23
37 to 48 inches	14.16	2.19	12.88	0.24	12.71	0.64	12.62	0.32
Kubanka Plots—								
Top 3 inches			10.62	2.18	10.22	2.09	12.21	2.45
4 to 7 inches			12.04	1.50	13.68	1.49	14.28	2.11
8 to 12 inches			10.18	1.47	10.91	1.17	11.58	1.57
13 to 24 inches			9.62	0.84	10.89	1.25	12.03	0.94
25 to 36 inches			11.29	0.86	11.71	0.78	13.06	0.96
37 to 48 inches			12.85	0.64	12.56	0.72	13.64	0.80

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 14 SEPTEMBER, 1915

Red Fife Plots—								
Top 3 inches	10.08	4.79	12.60	5.70	11.62	3.85	11.90	5.76
4 to 7 inches	12.54	2.62	13.22	3.11	12.75	3.02	13.56	3.45
8 to 12 inches	13.40	3.29	12.01	2.05	11.09	1.95	12.01	2.21
13 to 24 inches	13.99	2.02	11.26	1.17	11.25	1.41	12.08	1.50
25 to 36 inches	13.81	1.93	12.28	0.87	12.32	0.95	12.41	1.03
37 to 48 inches	13.63	1.85	12.93	0.87	12.30	0.87	15.75	0.82
Kubanka Plots—								
Top 3 inches			10.38	3.25	12.47	2.78	12.68	4.85
4 to 7 inches			12.93	1.59	14.18	2.02	15.10	2.53
8 to 12 inches			11.30	1.25	12.08	1.26	12.44	1.27
13 to 24 inches			10.81	0.70	11.09	0.47	11.98	1.10
25 to 36 inches			12.74	0.24	12.17	0.39	12.93	0.78
37 to 48 inches			14.38	0.00	13.43	0.16	13.31	0.40

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MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 28 SEPTEMBER, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	16.86	2.50	17.91	2.96	17.90	2.54	17.75	3.38
4 to 7 inches	15.91	5.70	16.40	4.65	16.84	4.76	16.96	6.69
8 to 12 inches	13.37	1.60	12.93	1.75	12.39	1.98	11.62	1.78
13 to 24 inches	14.14	1.21	11.30	0.78	11.53	0.78	11.14	0.86
25 to 36 inches	14.08	1.13	12.50	0.56	12.29	0.47	11.20	0.39
37 to 48 inches	13.52	1.60	12.77	0.24	13.11	0.24	11.32	0.00
Kubanka Plots—								
Top 3 inches			15.98	3.80	16.91	3.25	17.17	3.44
4 to 7 inches			16.00	4.30	15.99	4.05	16.77	4.59
8 to 12 inches			11.38	1.80	13.36	1.92	14.45	1.95
13 to 24 inches			10.92	0.78	11.69	0.71	13.07	0.48
25 to 36 inches			12.88	0.40	12.56	0.40	13.53	0.48
37 to 48 inches			14.36	0.32	13.43	0.32	13.87	0.08

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 25 OCTOBER, 1915

Red Fife Plots—								
Top 3 inches	No separate samples		14.82	2.09	15.16	1.80	14.84	3.34
4 to 7 inches	taken, same as		17.05	2.26	17.43	1.93	17.08	5.03
8 to 12 inches	Section 1800		16.72	2.68	16.88	3.51	16.72	3.84
13 to 24 inches			16.05	1.90	16.25	2.16	16.51	2.99
25 to 36 inches			15.12	0.41	14.92	0.98	14.36	0.81
37 to 48 inches			13.78	0.32	13.56	0.56	13.19	0.64
Kubanka Plots—								
Top 3 inches			13.68	2.26	14.88	1.71	14.67	1.71
4 to 7 inches			16.98	3.01	17.37	1.85	17.16	1.51
8 to 12 inches			16.39	3.82	17.25	2.60	16.91	2.50
13 to 24 inches			15.72	1.73	16.38	2.08	16.66	1.92
25 to 36 inches			14.65	0.57	15.49	0.58	15.51	0.50
37 to 48 inches			15.06	0.49	14.48	0.57	14.64	0.25

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MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 22 NOVEMBER, 1915

Depth	Section 1800, Fallow		Section 1700		Section 1800		Section 1900	
	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million	Moisture Per cent	Nitric Nitrogen Parts per Million
Red Fife Plots—								
Top 3 inches	No samples taken		10.97	2.73	11.81	3.70	11.99	3.16
4 to 7 inches			15.29	2.05	14.96	3.43	15.37	3.95
8 to 12 inches			15.60	2.54	15.52	3.95	15.44	2.30
13 to 24 inches			15.50	2.14	15.40	2.54	15.65	1.81
25 to 36 inches			14.52	0.49	14.15	0.80	14.40	0.49
37 to 48 inches			13.58	0.16	13.90	0.57	12.94	0.32
Kubanka Plots—								
Top 3 inches	No samples taken		10.60	2.48	8.83	2.58	12.14	2.68
4 to 7 inches			14.70	3.26	15.34	2.45	15.36	4.59
8 to 12 inches			15.26	2.53	15.00	3.98	16.26	3.32
13 to 24 inches			14.69	1.95	15.19	2.21	15.58	2.63
25 to 36 inches			13.99	0.57	14.34	0.88	14.85	0.89
37 to 48 inches			15.17	0.66	13.89	0.24	14.43	0.88

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 13 DECEMBER, 1915

Red Fife Plots—								
Top 3 inches			11.21	4.31	8.78	4.35	10.46	5.90
4 to 7 inches			15.42	3.87	14.61	3.83	14.86	5.06
8 to 12 inches			15.78	4.46	15.94	4.63	15.62	4.69
13 to 24 inches			15.52	2.97	15.16	3.52	15.62	2.72
25 to 36 inches			14.15	2.08	14.18	2.19	11.38	1.42
37 to 48 inches			13.78	1.46	13.65	2.26	14.44	1.14
Kubanka Plots—								
Top 3 inches			10.51	4.51	10.78	4.37	10.91	4.76
4 to 7 inches			15.20	3.77	15.34	3.11	15.62	3.79
8 to 12 inches			15.36	3.78	15.93	3.56	16.05	4.31
13 to 24 inches			14.37	3.25	15.52	3.20	15.60	3.79
25 to 36 inches			13.37	1.77	14.74	2.21	14.57	1.91
37 to 48 inches			14.40	1.71	14.46	1.47	14.30	1.66

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MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 16 FEBRUARY, 1916

Depth	Section 1800 Moisture percent	Section 1800 Nitric Nitrogen Parts per Million	Depth	Section 1800 Moisture percent	Section 1800 Nitric Nitrogen Parts per Million
Red Fife Plots—			Kubanka Plots—		
Top 3 inches	16.108	4.63	Top 3 inches	15.083	5.57
4 to 7 inches	16.607	4.10	4 to 7 inches	16.450	4.71
8 to 12 inches	16.717	4.34	8 to 12 inches	16.944	5.50
13 to 24 inches	15.834	2.46	13 to 24 inches	15.210	1.73
25 to 36 inches	12.947	0.70	25 to 36 inches	13.589	0.80
37 to 48 inches	13.492	0.64	37 to 48 inches	14.075	0.64

MOISTURE AND NITRIC NITROGEN IN SAMPLES TAKEN 22 MARCH, 1916

	Section 1700		Section 1800		Section 1900	
	Moisture	Nitric Nitrogen	Moisture	Nitric Nitrogen	Moisture	Nitric Nitrogen
Red Fife Plots—	Percent	Parts per Million	Percent	Parts per Million	Percent	Parts per Million
Top 3 inches	9.774	4.59	8.981	5.35	9.145	6.12
4 to 7 inches	16.234	4.63	18.456	4.07	15.549	4.67
8 to 12 inches	14.488	3.70	15.056	3.12	15.010	3.51
13 to 24 inches	15.095	1.64	15.369	1.88	15.621	1.97
25 to 36 inches	13.764	0.88	13.853	0.88	14.515	0.65
37 to 48 inches	13.367	0.64	13.465	0.64	14.238	0.32
Kubanka Plots—						
Top 3 inches	12.611	6.02	9.608	7.19	9.429	5.35
4 to 7 inches	16.096	4.88	15.394	4.34	16.392	4.46
8 to 12 inches	15.357	3.61	15.850	3.61	16.260	3.14
13 to 24 inches	14.587	2.11	15.456	2.12	15.593	1.64
25 to 36 inches	13.588	1.21	13.929	0.88	14.649	0.65
37 to 48 inches	14.602	0.65	13.636	0.24	14.057	0.57

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We took no samples for the determinations of moisture and nitric nitrogen in January because the weather was unfavorable and the ground frozen. We took only two series of samples in February, i.e. on the 16th of the month when we found the ground frozen to a depth of six inches. A comparison of the results obtained for the samples taken 13 December, 1915, with those obtained for the same section in February and again in March, 1916, shows that the distribution of the nitric nitrogen had changed during the interval between 13 December, 1915 and 16 February, 1916, but had remained essentially the same from 16 February to 22 March, 1916. These differences in the distribution are most marked in the third and fourth foot. Concerning the total amount present in the soil, there is in every case less in the second, third and fourth foot, in the two last series of samples taken, than in those taken 13 December, 1915, but more than in those taken 22 November, 1915. The surface foot shows an increase but it is not sufficient to balance the loss in the bottom three feet.

CONCERNING THE DISTRIBUTION OF MOISTURE

The rainfall in 1913 was only 6.77 inches during the growing season and this fell during two periods, the first from 9 to 20 May and the second from 13 to 23 July, with almost no cloudy weather. In 1915 we had 13.47 inches rainfall distributed rather evenly throughout the corresponding period. In July, we had only 2.12 inches rainfall, but this was distributed over eleven days and a "trace" is recorded on five days. Only eleven days during the month are recorded as clear. In 1913, we had a greater rainfall during this month, but its distribution was different and the cloudiness was very much less; there was only one day designated as wholly cloudy. The moisture in the soil, as shown by our samples, was much more clearly alike during the two seasons than one would expect, taking the very different weather conditions into consideration. But it must be remembered that we allowed a few days to elapse after a rain before we took our soil samples. These samples, except those designated fallow, were taken from cropped land. Determinations of moisture in the surface samples immediately after a rain would have had no object whatever for our purposes. A comparison of the tables given for 1913, in Part I (Bulletin 208), with those given for 1915 in the preceding pages, will show no regularity in the differences, which are much less than we would expect, two percent being about the maximum.

I deem it almost useless to state that the time of the rainfall, the cloudiness and temperature are much more important than the amount of the rainfall. Every farmer in the extreme eastern states is aware of this, for a few warm, foggy days with no rainfall may ruin the most flattering prospects for a wheat crop. Warm, cloudy weather, with but little wind and enough rain to keep the plants wet

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for a few days at the critical period in the development of the wheat may ruin the crop. It is in this manner that moisture enters into our problem of producing a crop rather than as a soil problem, provided that there is not at any time a decided deficiency in the soil. The moisture in these experimental plots for the two years 1913 and 1915 varied from approximately 12 to 17 percent, except at periods of irrigation or rainfall.

An excessive amount of water in the soil might drown the plants or it might dilute the nutrients in the soil, or even wash them out to such an extent as to be detrimental. We have no proof in the data so far obtained that the latter is the case to such an extent that we should give it any consideration in this place.

The distribution of the nitrates in the soil, particularly in the top two feet, is very largely determined by the water received at the surface. We endeavored in 1913 to follow this effect to a depth of 12 feet.*

At the end of April, we found the distribution of the nitrates in the soil taken to 12 feet very varying, but the nitrates were quite abundant within this depth. The application of one foot of water at one time sufficed to move the most of the nitrates to a greater depth. The frequent light rains of 1915 effected a different distribution of the nitrates in the top two feet of the soil from that which we had in 1913. I do not think that this was any disadvantage to the 1915 crop. It may have, and probably did, change the point of most active feeding within this depth, but was probably without further effect. In 1913 the surface foot was markedly the richest area; in 1915 the nitrates were more evenly divided between the top two feet.

The total amount of the nitric nitrogen present in the four feet of soil sampled during the two seasons is much more nearly uniform than we would expect to find it. There are such variations as we know to prevail in different sections taken on the same date. These variations are often relatively large both for any given foot, and also for samples representing from four to twelve feet. We have a few samples taken to a depth of four feet which are comparable, as they were taken from the same plots. On 14 July, 1913, we found nitric nitrogen equivalent to 260.3 pounds of sodic nitrate, and in another sample, 277.3 pounds; on the same date 1915, we found 273.2 pounds per acre.

The effect of the growing crop upon the amount of nitric nitrogen in the soil is very clearly shown during both seasons. The following data are obtained from the same plot of ground fallow and occupied by wheat: On 14 July, 1913, nitric nitrogen in the top four feet of fallow ground was equal to 260.36 pounds sodic nitrate, and in the cropped land to 120.36 pounds; on 8 July, 1915, it

* Part I (Colorado Exp. Sta. Bulletin 208), pp. 14 and 15.

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was equal to 263.2 and 91.6 pounds, respectively.

Lyon and Bizzell of Cornell University have shown that the nitrifying efficiency of soil occupied by wheat is depressed, and this may account for a part of the difference.* But the results, taken as they stand, show a very decided difference between the fallow ground and that occupied by the plants. An examination of the 160 series of samples taken shows this to be uniformly the case, but in varying degrees.

This suppression of the nitrates, be it due to the utilization of the nitric nitrogen or the suppression of the nitrifying efficiency of the soil or to both, is certainly only a temporary result, for as soon as the wheat has ripened, the production of nitrates goes on rapidly, as the following results summarized from the data previously given shows. The equivalent sodic nitrate is given for the four feet sampled:

TOTAL SODIC NITRATE, FOUR-FOOT SECTIONS OF SOIL†

		1913		1915	
		Section 1800	Section 1900	Section 1800	Section 1900
12 May	Fife	459.7	340.6	440.4	489.6
1 Aug.	Fife	114.0	107.8	91.9	51.7
30 Aug.	Fife	....	....	102.7	80.3
22 Nov.	Fife	....	....	179.0	136.3
13 May	Kubanka	333.2	213.3	465.8	485.0
1 Aug.	Kubanka	155.9	81.4	51.4	38.9
30 Aug.	Kubanka	....	....	102.2	112.1
22 Nov.	Kubanka	....	....	154.3	191.6

† The results have been calculated as sodic nitrate.

The plants had not developed enough by 12 May in either year to make much difference betwen these plots and fallow ground. The figures given for 1 August, however, are really not altogether comparable, because in 1913 the plants were practically ripe on this date, but were two weeks later in 1915, so that the data for 30 August, 1915, are much more nearly comparable with those of 1 August, 1913, than are those of 1 August, 1915. In either case we see that a very large amount of nitrogen has disappeared. The irrigation may have washed out a large percentage of it, as we found in 1913 that the application of one foot of water sufficed to remove the larger part of the nitrates to a greater depth than 12 feet. That the irrigation did not make the difference in 1915 is indicated by the results obtained on a fallow plot used as a check. (See the tables for 18 June and 8 July.) The land was irrigated 12 June, but owing to the already abundant supply of moisture in the soil, this plot received only 0.60 of an acre-foot, which did not suffice to do much if any leaching. We are forced, I think, to attribute the depression of the nitrates to the action of the plants, either by inhibiting the formation of the nitrates or by using them up. The wheat

* Journal of the Franklin Institute. Jan. and Feb. 1911, p. 220.

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on the plots that did not receive an application of the sodic nitrate did not indicate an excessive supply of these salts, nor did it show any deficiency, so far as growth and color of the plant may be depended upon as criteria for our judgment. As soon as the crop was removed the accumulation of nitric nitrogen took place rapidly and the ground was comparable to fallow land, especially as I had it double disced and there was at all times an adequate supply of moisture. The cropped plots had very nearly overtaken the fallowed check by the end of September. The rate of increase in the nitric nitrogen or its equivalent amount of sodic nitrate is clearly shown in the table just given, from which we see that we have a maximum increase of about five-fold from 38.9 to 191.6 pounds of sodic nitrate between 1 August and 22 November.

In my preceding statements concerning the nitric nitrogen, I have assumed that a glance at the tables given would suffice to make this subject clear, but it may be well to present it in another manner. In the following table I have converted the nitric nitrogen into its equivalent amount of sodic nitrate, and given the amount found in the first foot and that in the succeeding three feet. We did not continue the taking of our samples later than 1 August in 1913, for we harvested a few days (4 to 6) later, but in 1915 we continued the taking of samples till 13 December.

DISTRIBUTION OF NITRATES IN THE FIRST FOOT AND THE SUCCEEDING THREE FEET OF SOIL IN 1913 AND 1915

Date	Variety of Wheat	Section	First Foot	Succeeding Three Feet
12 May 1913	Red Fife	1800	254.2	205.4
13 May 1915	Red Fife	1800	124.4	316.0
12 May 1913	Red Fife	1900	150.1	190.6
13 May 1915	Red Fife	1900	115.7	373.9
1 Aug. 1913	Red Fife	1800	71.8	42.3
3 Aug. 1915	Red Fife	1800	29.3	62.6
1 Aug. 1913	Red Fife	1900	62.0	45.8
3 Aug. 1915	Red Fife	1900	19.5	32.2
30 Aug. 1915	Red Fife	1800	42.2	60.5
30 Aug. 1915	Red Fife	1900	50.6	29.7
22 Nov. 1915	Red Fife	1800	89.1	89.1
22 Nov. 1915	Red Fife	1900	73.6	62.8
14 Dec. 1915	Red Fife	1800	108.1	191.3
14 Dec. 1915	Red Fife	1900	121.8	118.7
12 May 1913	Kubanka	1800	186.1	147.0
13 May 1915	Kubanka	1800	117.7	348.1
12 May 1915	Kubanka	1900	142.0	71.4
13 May 1915	Kubanka	1900	117.1	367.9
1 Aug. 1913	Kubanka	1800	94.7	61.2
3 Aug. 1915	Kubanka	1800	19.8	32.5
1 Aug. 1913	Kubanka	1900	49.0	32.4
3 Aug. 1915	Kubanka	1900	12.3	26.6
30 Aug. 1915	Kubanka	1800	36.2	66.0
30 Aug. 1915	Kubanka	1900	47.3	64.8
22 Nov. 1915	Kubanka	1800	74.4	80.0
22 Nov. 1915	Kubanka	1900	86.0	105.6
14 Dec. 1915	Kubanka	1800	86.7	164.8
14 Dec. 1915	Kubanka	1900	104.1	176.64

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It will be noticed that in 1913 the first foot of soil usually contained more nitrates than the succeeding three feet, except on 12 May, whereas this is not true to the same extent in 1915. In other words, the frequent rains of 1915 caused the nitrates to pass below the first foot. This was not due to the difference in the amount of water received during the months considered, for that was approximately the same during the respective seasons, about 19 inches, nor was it due to differences in soil, for we used the same plots, nor to the wheat, for we used the same varieties, but to the distribution of the water applied to the surface throughout the season.

THE TOTAL NITROGEN

On 27 June, 1913, we sampled three sections of soil to a depth of eleven feet, making a separate sample of each foot of the section. These samples agreed in showing that the surface foot contained, roughly, twice as much nitrogen as the second, and the second twice as much as the third, but from the third downward, including the eleventh foot, the amount of the total nitrogen remained fairly constant, at about 0.02 percent. In such four-foot samples, we took during this season of 1913, six sets of them, the same fact was shown, i. e., that the total nitrogen in the fourth foot was about 0.02 percent, or between this and 0.03 percent. These samples were taken from fallow land, but six sets taken from the cropped land showed essentially the same thing. We cannot say that the samples as taken showed any regular differences in the nitrogen in the first, or any succeeding foot in favor of the fallow land which would justify any attempt to interpret them.

In 1915 we determined the total nitrogen in 19 series of samples taken to a depth of four feet. These agree in showing that the total nitrogen falls to an amount equal to from 0.02 to 0.03 percent in the fourth foot. The samples taken 13 May, before the plants had attained any considerable development, showed that the surface foot was perceptibly richer in total nitrogen than on the two subsequent dates, 1 September and 25 October, when these determinations were repeated. The same fact holds to even a greater extent for the nitric nitrogen, as the table last given shows for the corresponding nitrates. Of course, we have in this question the two serious difficulties which confront us in this work, i. e., the difficulty of obtaining samples which are comparable even when taken from as nearly the same spot as possible without seeking the identical spot where we made the preceding boring, and the further question in regard to the importance that we are justified in attaching to a few ten-thousandths or even thousandths of one percent. There can be no question but that differences as small as, or even smaller than, thousandths of one percent, not only may, but are, of significance in these problems. If any question be entertained on

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this point, we have only to consider the results produced by the addition of 40 pounds of nitrogen to the acre, an amount equal to 0.001 percent calculated on a foot of soil. The application of this amount at the time of seeding, and harrowed in to a depth of three inches, suffices to change the growth of the crop and the character of the wheat. In determining the total nitrogen we involve all of the nitric nitrogen that may be present and other unstable forms to such an extent that the differences obtained in our analyses are difficult, if not impossible, of interpretation with any degree of certainty. We have, for instance, on 13 May, 1915, in Section 1800, Fife, a total of 5,305 pounds of nitrogen in the surface acre-foot; on 1 September in the same land cropped to wheat, 4,350, and in a check plot kept fallow, 4,684 pounds. We have for this land a loss of 625 pounds of nitrogen for the surface acre-foot between 13 May and 1 September. This is without the crop, but with the crop of wheat we have a further loss of 334 pounds. Some of this may have been washed below the depth to which we took our samples and this may have been lost. There are too many undetermined factors at play in this question to permit us to interpret our results. There have been, without doubt, both gains and losses, some of the latter due to the crop, but just to what extent we do not know. It seems very improbable that the loss of 334 pounds of nitrogen, noted above, is due directly to the crop, which did not remove, as a mature crop, more than a sixth or, at most, a fifth of this amount. The crop of grain removed was 33 bushels per acre and the straw weighed 4,750 pounds, which, together, would not remove a fifth of this deficit, 334 pounds. The analytical results themselves are as good as can be gotten; this is not the trouble, but other difficulties inherent in the problem.

PERCENTAGE OF TOTAL NITROGEN IN SOIL OF WHEAT PLOTS—SEASON 1915

Date	Depth	Section 1700 Fife	Section 1800 Fife	Section 1900 Fife	Section 1700 Kubanka	Section 1800 Kubanka	Section 1900 Kubanka	Section 1800 Fallow
13 May	Top 3 inches	.1393	.1279	.1331	.1368	.1327	.1373	Not
	4 to 7 inches	.1441	.1403	.1382	.1421	.1385	.1439	sampled
	8 to 12 inches	.1322	.1293	.1316	.1212	.1315	.1328	Same as
	13 to 24 inches ...	.0718	.0645	.0737	.0669	.0700	.0711	Section
	25 to 36 inches ...	.0351	.0349	.0477	.0339	.0383	.0374	1800
	37 to 48 inches ...	.0332	.0277	.0295	.0289	.0273	.0287	Fife
1 Sept.	Top 3 inches	.1205	.1113	.1243	.1198	.1239	.1260	.1202
	4 to 7 inches	.1251	.1123	.1208	.1218	.1224	.1282	.1226
	8 to 12 inches	.1045	.1044	.0984	.1130	.0994	.1046	.1108
	13 to 24 inches ...	.0561	.0506	.0578	.0523	.0562	.0553	.0551
	25 to 36 inches ...	.0297	.0274	.0332	.0294	.0338	.0292	.0295
	37 to 48 inches ...	.0190	.0175	.0214	.0245	.0244	.0247	.0224
25 Oct.	Top 3 inches	.1274	.1196	.1241	.1224	.1193	.1255	
	4 to 7 inches	.1157	.1263	.1292	.1307	.1145	.1108	Not
	8 to 12 inches	.0985	.0979	.0901	.0915	.1102	.1004	sampled
	13 to 24 inches ...	.0530	.0506	.0549	.0494	.0441	.0517	
	25 to 36 inches ...	.0327	.0275	.0341	.0305	.0353	.0308	
	37 to 48 inches ...	.0240	.0223	.0253	.0227	.0233	.0226	

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The results of 1915 agree very closely with those obtained in 1913 showing that the total nitrogen falls, practically, to a constant at a depth of three feet. This was not the case with the nitric nitrogen, as is shown by the samples taken 29 April, 1913, to a depth of 12 feet. The distribution of nitric nitrogen in these was very erratic. (See Part I (Colorado Bulletin 208) p. 20). It is quite common in our samples to find that the fourth foot contains less than one-tenth as much nitric nitrogen as the first foot, but it may contain as much or more, or again it may contain no nitric nitrogen.

It has been intimated that we have considered the difficulty in obtaining samples on different dates, that would have been the same, had the samples been taken on the same date. This difficulty is real and is well shown by the results obtained with 150 samples taken from as many contiguous square feet. These results are given in Part I (Colorado Bulletin 208) p. 26, where we find a difference of 354 pounds of nitrogen in the surface foot. This difference is even larger than that found for the plot sampled on 13 May and 1 September, 1915, before and after the crop had been grown. This difficulty is not to be avoided in the case of field experiments. Recourse must be had to other methods of experimentation which was contemplated from the beginning of this work.

We have now given the weather conditions, the moisture in the soil, the nitric and total nitrogen in the soil for 1915, and compared these factors with the results for 1913. The two seasons were wholly unlike; the principal differences were that the temperature in 1915 was lower, and there was about twice the amount of rainfall. Its distribution was much more general than in 1913, when over two-thirds of the total for the growing season, 6.77 inches, fell in May and July. In 1913 the rainfall for July was confined to a period of not more than 12 days, including several on which either no rain or only a very small amount fell. The total water, rainfall and irrigation, received during the two seasons, was essentially the same, about 19 inches. The moisture in the soil samples taken in 1915 was a little higher, the average being between one and two percent. The effects of these weather conditions on the amount of the nitrates in fallow land, taken to a depth of four feet, were small. The maximum difference was equivalent to 13 pounds of sodic nitrate in the top four feet. The more even distribution of the water received by the land in 1915 brought about a different distribution of the nitrates, but we have no proof that they were removed beyond the feeding area of the plants, which we assume may extend in this soil, to a depth of four feet. There is no indication that the dilution of the nitrates in the soil was such as to affect in any way the growth of the crop. This last statement does not include any reference to the composition of the crop.

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The total nitrogen is slightly higher in 1915 than in 1913. While this is subject to variation, due to the difficulties of sampling, it is true of so many samples that we may perhaps give it some weight even though the differences are very small. The soil conditions vary less in the two seasons than the weather conditions led me to expect.

THE EFFECTS OF INDIVIDUAL FERTILIZERS UPON THE GROWTH OF THE PLANTS

In Part I (Bulletin 208), p. 31, et seq., we stated that we could not discern any differences in the growth and ripening of the plants on the various plots, except on those that had received a dressing of sodic nitrate. The smallest amount of this salt applied, equal to 40 pounds of nitrogen, sufficed to produce a very marked difference in the color, growth, and tendency of the plants to lodge. The tendency to lodge varied considerably in the different varieties of wheat used. The Defiance seemed most susceptible. We would not be justified in asserting that 40 pounds of nitrogen per acre produced as serious results as 120 pounds, still it was enough to cause the plants to show its effects just as sharply as the 120 pounds, and to cause the wheat to lodge very badly, the plants to rust, and to produce, even when not attacked by rust, shrunken wheat. The results in 1915 were of the same character as in 1913, but owing to the frequent, light rains and the very luxuriant growth of the plants, the lodging and rusting were worse than in 1913. The yield of the Defiance on the plots that were dressed with sodic nitrate ranged from 9 to 13 bushels of very badly shrunken wheat. The wheat of this variety, Defiance, was all badly shrunken in 1915, but the plots which had received an application of sodic nitrate produced much poorer grain than the others; it was so badly shrunken that it could scarcely be considered grain at all. There can be no question but that the sodic nitrate tends to produce shrunken wheat, but in both 1914 and 1915 the most important cause was rust on the plants.

The following data will enable the reader to judge of the effects of the various fertilizers upon the development of the plant as grown under our conditions. The following table gives a sort of correlation of these effects:

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EFFECTS OF FERTILIZERS UPON THE DEVELOPMENT OF PLANTS* 1914

Fertilizer per acre	DEFIANCE				RED FIFE				KUBANKA			
Section 1700	Average height in inches	Average length of heads in inches	Average number of spikelets	Average number of kernels per spikelet	Average height in inches	Average length of heads in inches	Average number of spikelets	Average number of kernels per spikelet	Average height in inches	Average length of heads in inches	Average number of spikelets	Average number of kernels per spikelet
120 pounds Nitrogen	52.1	4.49	19.8	2.20	51.4	3.93	16.2	2.10	59.6	2.78	18.0	2.67
60 pounds Phosphorus	50.9	3.99	18.1	2.56	52.1	3.74	15.6	1.80	56.8	2.61	16.5	2.62
200 pounds Potassium	48.0	3.96	18.3	2.50	50.4	3.70	15.3	. . .	55.3	2.58	16.1	2.48
None	48.7	4.07	18.5	2.31	52.2	3.80	15.5	. . .	56.5	2.66	16.7	2.50
Section 1800												
80 pounds Nitrogen	51.5	4.34	19.5	2.26	54.1	3.90	16.4	2.21	59.8	2.68	18.0	2.62
40 pounds Phosphorus	52.1	4.09	18.9	2.44	50.6	3.60	15.1	1.80	61.6	2.50	16.7	2.98
150 pounds Potassium	50.4	3.90	18.0	2.44	48.3	3.60	15.1	1.90	53.9	2.50	16.2	2.42
None	52.2	4.06	18.7	2.32	49.6	3.60	14.8	. . .	57.0	2.54	16.6	2.73
Section 1900												
40 pounds Nitrogen	54.8	4.28	19.0	2.35	56.2	3.85	16.3	2.00	57.4	2.64	17.0	2.11
20 pounds Phosphorus	52.1	4.18	19.0	2.39	50.3	3.67	15.5	. . .	55.9	2.55	16.5	2.27
100 pounds Potassium	50.6	3.79	17.1	2.46	50.2	3.50	14.6	1.80	49.3	2.49	15.5	2.45
None	56.1	3.88	18.0	2.51	51.1	3.60	14.8	. . .	58.1	2.50	16.4	2.28

* Averages are based on 100 plants taken without selection

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It appears from this table that the shortest plants, with the shortest heads, were produced on the plots receiving potassium. The lowest average kernels per spikelet is found for those plots to which nitrates had been applied, but we find here the highest average for the length of head. This last is the only feature that holds throughout the table and this is not very pronounced. This table shows that the effects of the fertilizers given are neither great nor uniform, even in the small effects produced. We might infer from the effect of the nitrates that an excessive food-supply lessens fecundity.

RATIO OF THE STEMS, LEAVES AND HEADS IN THE GREEN PLANTS

The following table, which gives the relative green weights of the stems, leaves and heads for the plants grown with the different fertilizers, shows a few differences in these ratios, but they are not constant. The figures are based upon 2,000-gram samples and the loss represents the waste in preparing and cutting them, including the evaporation that took place. This was often very considerable, especially if the plants were wet, due to external moisture, which was often the case and unavoidable, as we had to cut the samples in the morning in order to handle them the same day.

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RATIO OF GREEN WEIGHTS OF STEMS, LEAVES AND HEADS OF RED FIFE, 1915

Date	Fertilizer	Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	67.38	19.50	12.03
13 July	Phosphorus, 60 pounds	68.45	16.25	12.80
13 July	Potassium, 200 pounds	67.46	14.34	13.96
13 July	None	69.86	15.90	12.41
23 July	Nitrogen, 120 pounds	70.00	9.25	20.15
23 July	Phosphorus, 60 pounds	66.85	7.40	24.00
23 July	Potassium, 200 pounds	65.75	6.75	26.50
23 July	None	68.85	8.85	21.40
6 Aug.	Nitrogen, 120 pounds	69.25	....	30.25
6 Aug.	Phosphorus, 60 pounds	62.10	....	36.85
6 Aug.	Potassium, 200 pounds	61.10	....	38.85
6 Aug.	None	63.00	....	35.35
16 July	Nitrogen, 80 pounds	64.81	20.06	13.04
16 July	Phosphorus, 40 pounds	67.11	17.11	13.05
16 July	Potassium, 150 pounds	64.97	15.43	17.43
16 July	None	68.55	14.34	14.83
27 July	Nitrogen, 80 pounds	60.00	17.00	19.85
27 July	Phosphorus, 40 pounds	58.00	15.10	25.00
27 July	Potassium, 150 pounds	56.20	13.85	28.00
27 July	None	59.40	14.90	24.65
9 Aug.	Nitrogen, 80 pounds	66.75	....	32.35
9 Aug.	Phosphorus, 40 pounds	62.35	....	36.25
9 Aug.	Potassium, 150 pounds	59.50	....	39.35
9 Aug.	None	58.75	....	39.95
20 July	Nitrogen, 40 pounds	64.00	13.00	17.00
20 July	Phosphorus, 20 pounds	64.50	15.60	18.50
20 July	Pottasium, 100 pounds	62.75	15.50	20.35
20 July	None	63.50	18.50	16.75
30 July	Nitrogen, 40 pounds	66.50	6.75	26.25
30 July	Phosphorus, 20 pounds	63.10	6.00	29.75
30 July	Potassium, 100 pounds	63.25	5.35	30.90
30 July	None	63.55	5.55	29.75
9 Aug.	Nitrogen, 40 pounds	66.25	....	32.35
9 Aug.	Phosphorus, 20 pounds	63.10	....	35.95
9 Aug.	Potassium, 100 pounds	63.10	....	35.70
9 Aug.	None	62.25	....	37.00

There is one exception to the statement that the nitrate plots yielded plants with heavier stems and leaves than the others, but this set of samples was taken quite early in the season. 16 July. It may be well to state, for the benefit of those who may compare the data given here with that given for 1913. that the plants at this time, 16 July, 1915, were several days (6 to 8) behind the plants on the same plots in 1913 in their development. It will be noticed that the weight of the heads, even up to 9 August, was as a rule less than from the other plots. This is entirely consonant with the results

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of the season as shown by the weight of the threshed grain. How much of this result is to be attributed to the effect of rust and how much to that of the nitrate itself, is not clear, besides, these two questions cannot be judged separately, for it was evident that the nitrate plots suffered more from rust than the other plots. This fact we attributed to the effect of the nitrate upon the condition of the plant, not simply because it was lodged, but also because the nitrate had rendered it a better plant for the rust to grow on. One effect of nitrate has been stated in a previous bulletin to be the bringing about of an abnormal ripening, even when the weather conditions are favorable to a normal ripening of the crop, and the quantity of nitrate is not sufficient to cause lodging.

THE DRY MATTER IN THE PLANTS OF 1915 CROP

The inference from the preceding discussion would be that the plants grown with nitrate were heavy in stems and leaves because they were bigger and not because they contained more water. This latter, however, was the case. The samples for 1913 showed this to be the case in every set of samples in comparison with plants grown with the application of phosphorus and potassium, which were either essentially equal to or less than those grown on the check plots. This excess of water tends to make the dry weight of the plants more nearly equal. The following table shows that the rule is that the plants grown on the plots which received potassium or phosphorus are the richest in dry matter, irrespective of variety, though the plants grown on the check plots are almost as rich, sometimes even richer in dry matter than those grown with phosphorus or potassium. The plants grown with the application of nitrates are, almost without exception, the poorest in dry matter, irrespective of the variety or the amount of nitrate applied. These observations are applicable to the samples of both seasons, 1913 and 1915, but the samples of the two seasons cannot be compared date by date, for the development of the plants in 1915 was retarded from 6 to 14 days, owing, I take it, to the weather conditions. This difference in the development of the plant increased with the season and the maximum difference was at the time of ripening. The ripening period was greatly influenced by the appearance of rust, which practically killed some of the Defiance.

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DRY MATTER IN PLANTS GROWN WITH DIFFERENT FERTILIZERS—SEASON 1915

Date	Section	Fertilizer	Defiance	Red Fife	Kubanka
13 July	1700	Nitrogen, 120 pounds	21.30	25.25	25.00
13 July	1700	Phosphorus, 60 pounds	25.99	29.49	29.90
13 July	1700	Potassium, 200 pounds	25.20	30.87	30.59
13 July	1700	None	24.63	28.12	27.34
14 July	1800	Nitrogen, 80 pounds	19.75	25.15	26.29
14 July	1800	Phosphorus, 40 pounds	20.04	28.33	30.00
14 July	1800	Potassium, 150 pounds	25.46	30.31	31.87
14 July	1800	None	23.16	27.65	32.03
15 July	1900	Nitrogen, 40 pounds	28.63	30.62	29.53
15 July	1900	Phosphorus, 20 pounds	28.59	30.93	33.59
15 July	1900	Potassium, 100 pounds	29.63	32.97	33.59
15 July	1900	None	29.33	31.40	31.56
21 July	1700	Nitrogen, 120 pounds	25.31	27.50	33.28
21 July	1700	Phosphorus, 60 pounds	31.87	36.72	36.25
21 July	1700	Potassium, 200 pounds	31.25	35.62	36.25
21 July	1700	None	29.53	36.87	36.87
24 July	1800	Nitrogen, 80 pounds	28.43	33.75	33.90
24 July	1800	Phosphorus, 40 pounds	36.40	40.62	40.62
24 July	1800	Potassium, 150 pounds	35.62	38.90	38.75
24 July	1800	None	33.90	39.69	41.25
26 July	1900	Nitrogen, 40 pounds	35.46	37.65	38.94
26 July	1900	Phosphorus, 20 pounds	37.57	39.37	39.76
26 July	1900	Potassium, 100 pounds	37.50	40.00	40.47
26 July	1900	None	36.56	39.22	40.15
4 Aug.	1700	Nitrogen, 120 pounds	36.82	40.47	37.97
4 Aug.	1700	Phosphorus, 60 pounds	43.90	46.72	45.00
4 Aug.	1700	Potassium, 200 pounds	43.43	45.78	44.37
4 Aug.	1700	None	39.84	45.47	43.75
5 Aug.	1800	Nitrogen, 80 pounds	35.31	41.72	43.90
5 Aug.	1800	Phosphorus, 40 pounds	42.50	45.00	46.09
5 Aug.	1800	Potassium, 150 pounds	41.40	46.25	44.53
5 Aug.	1800	None	40.93	45.47	47.19
10 Aug.	1900	Nitrogen, 40 pounds	44.84	49.07	51.25
10 Aug.	1900	Phosphorus, 20 pounds	48.12	52.65	51.25
10 Aug.	1900	Potassium, 100 pounds	49.84	53.90	50.78
10 Aug.	1900	None	47.65	52.65	48.75

The dry matter given in the preceding table is the weight of the air-dried plants. In 1913 we found the air-dried material to contain from 5.566 to 8.652 percent of moisture; in 1915 we find the amount of moisture, in the few samples on which this determination has been made, much more uniform from 5.00 to 5.68 percent. It is but fair to state that all of the determinations made were on samples of Red Fife and may not hold strictly for the other varieties. The results, however, indicate that we are justified in assuming that the term air-dried means that the plants still contain an average of

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not more than 7.5 percent of moisture, which is the average found for 1913.

The series of samples taken in 1915 is much larger than that taken in 1913, but the samples representing the same period of development yield quite closely agreeing results, which indicates that the influence of the weather upon this factor was much less than one would expect and further, that these conditions in no way eliminated or greatly modify the influence of the individual fertilizers.

Apropos of the influence of the date upon the development of the plant it may be added that the individual fertilizers are not wholly without effect upon this. It was a noticeable feature of the fields at one period in 1914 and again in 1915 that the wheat on the plots to which potassium had been applied was taller and appeared to be more advanced than that in the other plots, but this difference was entirely obliterated in a few days and afterwards no difference between these and the other plots could be observed.

THE EFFECT OF FERTILIZERS UPON THE NITROGEN CONTENT OF THE PLANTS

We do not wish to change any of the statements made in Part I (Bulletin 208), p. 35, in regard to the reasons for presenting this subject, the scope of the work, or the variety chosen. All that we then said applies to our work still.

We will add, however, the subject of the nitric nitrogen in the plant. This subject was passed over in Part I (Bulletin 208) because we wished to repeat our observations and extend our analytical work, which we have been able to do during the present season, and the results will be given in their proper place.

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TOTAL AND PROTEID NITROGEN IN GROWING WHEAT PLANTS, 1915

Date	Fertilizer	Total			Proteid		
		Stems	Leaves	Heads	Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	.2797	.8092	.6324	.1598	.5838	.4066
13 July	Phosphorus, 60 pounds ...	.2050	.6150	.5629	.1270	.3946	.3614
13 July	Potassium, 200 pounds ...	.2050	.5907	.5808	.1286	.4170	.3683
13 July	None	.1911	.5837	.5456	.1216	.3981	.3545
16 July	Nitrogen, 80 pounds	.2777	.6463	.6376	.1843	.5018	.4289
16 July	Phosphorus, 40 pounds ...	.2064	.4639	.5872	.1529	.3892	.4045
16 July	Potassium, 150 pounds ...	.2359	.4934	.6185	.1494	.3753	.4149
16 July	None	.2102	.5786	.5959	.1490	.4309	.3598
20 July	Nitrogen, 40 pounds	.2613	.4361	.5803	.1891	.3662	.4274
20 July	Phosphorus, 20 pounds ...	.2376	.4100	.5699	.1703	.3475	.3906
20 July	Potassium, 100 pounds ...	.1963	.3179	.5542	.1425	.2828	.3788
20 July	None	.2120	.3509	.5629	.1430	.2884	.3732
23 July	Nitrogen, 120 pounds	.3457	1.2561	.7644	.2220	.1077	.5386
23 July	Phosphorus, 60 pounds ...	.2357	.6915	.6376	.1668	.0312	.4392
23 July	Potassium, 200 pounds ...	.1998	.6880	.5924	.1390	.0660	.4378
23 July	None	.2324	.6915	.6116	.1613	.5052*	.4309
27 July	Nitrogen, 80 pounds	.2884	.4621	.6533	.1824	.3461	.6533
27 July	Phosphorus, 40 pounds ...	.1964	.2187	.5212	.1432	.1703	.5212
27 July	Potassium, 150 pounds ...	.2187	.2988	.5872	.1613	.2168	.5838
27 July	None	.1928	.2797	.5247	.1390	.2234	.5247
30 July	Nitrogen, 40 pounds	.2654	1.0260	.7297	.1842	.5699	.5734
30 July	Phosphorus, 20 pounds ...	.2204	.7679	.6585	.1703	.6116	.4934
30 July	Potassium, 100 pounds ...	.2015	.5942	.6550	.1369	.1890	.5365
30 July	None	.2102	.7401	.6324	.1543	.2954	.4830
6 Aug.	Nitrogen, 120 pounds	.4169		.9221	.2967		.7794
6 Aug.	Phosphorus, 60 pounds ...	.2289		.6759	.1598		Lost
6 Aug.	Potassium, 200 pounds ..	.2154		.7210	.1369		.5817
6 Aug.	None	.2671		.6533	.1855		Lost
9 Aug.	Nitrogen, 80 pounds	.4500		.9069	.2898		.7401
9 Aug.	Phosphorus, 40 pounds ...	.2498		.6741	.1876		.5595
9 Aug.	Potassium, 150 pounds ...	.2726		.7747	.2030		.6568
9 Aug.	None	.2550		.7019	.1890		.5699
12 Aug.	Nitrogen, 40 pounds	.3787		.8895	.2780		.8023
12 Aug.	Phosphorus, 20 pounds ...	.3110		.7158	.2255		.6950
12 Aug.	Potassium, 100 pounds ..	.2272		.8286	.1703		.7815
12 Aug.	None	.2726		.8040	.2050		.6915

* This result appears abnormal. The whole set was repeated with the same results.

The table, when compared with a similar statement obtained for the crop of 1913, indicates that the amounts of total and proteid nitrogen are smaller throughout the season of 1915 than in 1913; the same conclusion is indicated for the dry matter, but when one considers plants of the same development we find that the difference in dry matter is not very pronounced, while the percentage of nitrogen is decidedly lower and holds, in the main, for the whole season. In both seasons we see that the application of nitrogen increased these forms of nitrogen in the plant, and these differences

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are quite as pronounced in 1915 as in 1913, showing that, while the season influenced the whole problem, it did not obscure the effects of the nitrate. The most noted differences are shown by the samples of the heads as they approached ripeness. The total nitrogen in the heads of the last four samples, gathered 5 August, 1913, averaged 1.2587 percent, but in those on 9 August, 1915, from the same plot of ground and of the same variety of wheat, the average was only 0.7644 percent. A difference is shown by the earliest samples gathered in the respective years, but the difference is smaller, 0.1675 against 0.4943 percent. The differences between the total nitrogen in the heads of the plants for the respective years increased as the plants matured. This was probably not due to the total supply of nitrogen in the soil, for, if we compare the plants grown with the application of 120 pounds of nitrogen per acre, in the form of sodic nitrate, at the time of full bloom, we find that the heads in 1913 contained 0.7607 percent of nitrogen; in 1915, the same variety, grown on the same land, and also with the application of 120 pounds of nitrogen, contained 0.6324, showing a difference of 0.1283 percent, which is a little less than the average found for all of the plots in this section, i. e., 0.1675. This difference increased during the season. These results, especially those obtained with mature plants, all involve the question of the effects produced by the abundant appearance of rust.

I have no way of estimating how great the influence of this factor was, nor of conveying any definite idea of the severity of the attack, but it was very bad, even on Red Fife, the variety used for the nitrogen work, while it ruined the Defiance. The factors appearing in this year's work are the fertilizers applied, the weather conditions, and the effects of the rust. The same factors were operative in 1913 also, but they were very different, the rainfall, for instance, in 1913, between 18 May and 7 July, the date on which the first samples of plants were taken, was 0.36 inch, in 1915, for the same period, 18 May till 13 July, the date of taking the first sample, it was 5.94 inches. In the former year we applied, on 12 June, one foot of water, in the latter 0.6 of a foot, also on 12 June, so that the amount of water received by the plots was essentially the same, but, in 1913 the water was applied to the land in practically one application, while the plants, throughout the period considered, were scarcely wet at all and the weather was clear. The quantity of water received in 1915 was smaller by less than one inch, but its application and distribution were different, the plants themselves being kept almost continuously wet by frequent light rains, and cloudiness prevented their rapid drying. The mean temperature, too, was a little lower in 1915 than in 1913. As the differences existed early in the season, before the appearance of the rust, we cannot

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consider the latter as the cause of it at that time. All that we can say is that the rust intensified this effect and apparently produced a similar if not an identical result. If we compare the ratio of the total nitrogen to the proteid nitrogen in the heads for the last eight samples taken in 1913, and for the last ten samples taken in 1915, we find it higher in 1913 than in 1915, 1.18 against 1.03; that is, the total and proteid nitrogen in the heads at the end of the season were more nearly equal in 1915 than in 1913, though both were decidedly lower in 1915. There was not only less protein in the whole plant than in 1913, but a larger percentage of it remained in the leaves and stems (straw).

AMMONIC AND AMID NITROGEN IN WHEAT PLANTS IN 1915

		Ammonic Nitrogen Per cent			Amid Nitrogen Per cent		
Date	Fertilizer per Acre	Stems	Leaves	Heads	Stems	Leaves	Heads
18 July	Nitrogen, 120 pounds	.00265	.00638	.00638	.00597	.00270	.00665
13 July	Phosphorus, 60 pounds ...	.00529	.00162	.00652	.00299	.00358	.00802
13 July	Potassium, 200 pounds ...	.00162	.00475	.00692	.00270	.00489	.00162
13 July	None	.00189	.00393	.00610	.00243	.00407	.00816
16 July	Nitrogen, 80 pounds	.00299	.00707	.01768	.01224	.00625	.01034
16 July	Phosphorus, 40 pounds ...	.00216	.00434	.00789	.00880	.00880	Lost
16 July	Potassium, 150 pounds ...	.00216	.00652	.01088	.00666	.00434	.01224
16 July	None	.00216	.00734	.00925	.00270	.00489	.01101
20 July	Nitrogen, 40 pounds	.00216	.00339	.00789	.00270	.00299	.00979
20 July	Phosphorus, 20 pounds ...	.00243	.00366	.00879	.00284	.00420	.00965
20 July	Potassium, 150 pounds ...	.00189	.00366	.00897	.00270	.00256	.00665
20 July	None	.00216	.00353	.00843	.00216	.00284	.01101
23 July	Nitrogen, 120 pounds	.00610	.00992	.01468	.00556	.01170	.01427
23 July	Phosphorus, 60 pounds ...	.00189	.00610	.00816	.00299	.00570	.00652
23 July	Potassium, 200 pounds ...	.00189	.00652	.00610	.00216	.00434	.00393
23 July	None	.00216	.00516	.00816	.00216	.00489	.00679
27 July	Nitrogen, 80 pounds	.00189	.00763	.00817	.00353	.00583	.00592
27 July	Phosphorus, 40 pounds ...	.00162	.00326	.00707	.00202	.00284	.00434
27 July	Potassium, 150 pounds ...	.00189	.00353	.00925	.00353	.00216	.00457
27 July	None	.00162	.00339	.00843	.00175	.00216	.00652
30 July	Nitrogen, 40 pounds	.00202	.01183	.00707	.00339	.01387	.00870
30 July	Phosphorus, 20 pounds ...	.00162	.00570	.00843	.00216	.00707	.00610
30 July	Potassium, 100 pounds ...	.00162	.00366	.00789	Lost	.00543	.00447
30 July	None	.00148	.00420	.00856	Lost	Lost	Lost
6 Aug.	Nitrogen, 120 pounds	.00679		.00665	.00643		.00707
6 Aug.	Phosphorus, 60 pounds ...	.00284		.00679	Lost		.00880
6 Aug.	Potassium, 200 pounds ...	.00353		.00462	.00420		.00407
6 Aug.	None	.00284		.00638	None		.00162
9 Aug.	Nitrogen, 80 pounds	.00734		.00353	.00816		.00747
9 Aug.	Phosphorus, 40 pounds ...	.00270		.00543	.00407		.00515
9 Aug.	Potassium, 150 pounds ...	.00407		.00353	.00570		.00489
9 Aug.	None	.00261		.00652	.00366		.00720
12 Aug.	Nitrogen, 40 pounds	.00762		.00734	.00638		.00543
12 Aug.	Phosphorus, 20 pounds ...	.00489		.00462	.00434		.00502
12 Aug.	Potassium, 100 pounds ...	.00543		.00462	.00407		.00353
12 Aug.	None	.00434		.00407	.00489		.00665

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NITRIC NITROGEN IN GREEN AND DRY WHEAT PLANTS 1915

Date	Fertiliser per Acre	Green Plants			Dry plants, but Calculated Back to Green Plants		
		Stems	Leaves	Heads	Stems	Leaves	Heads
13 July	Nitrogen, 120 pounds	.02269	.01341	None			
13 July	Phosphorus, 60 pounds ...	Trace	None	None			
13 July	Potassium, 200 pounds ...	.00054	None	None	No samples preserved		
13 July	None	None	None	None			
16 July	Nitrogen, 80 pounds	.01996	.01179	None			
16 July	Phosphorus, 40 pounds ...	None	None	None			
16 July	Potassium, 150 pounds ...	.00039	None	None			
16 July	None	Trace	None	None			
20 July	Nitrogen, 40 pounds	.00620	.00069	None	.02163	.00514	None
20 July	Phosphorus, 20 pounds ...	.00043	None	None	.00087	None	None
20 July	Potassium, 100 pounds ...	.00024	None	None	None	None	None
20 July	None	None	None	None	None	None	None
23 July	Nitrogen, 120 pounds	.02886	.01226	.00048	.01995	.01954	.00014
23 July	Phosphorus, 60 pounds ...	None	None	None	.00028	None	None
23 July	Potassium, 200 pounds ...	None	None	None	.00024	None	None
23 July	None	None	None	.00034	None	None	None
27 July	Nitrogen, 80 pounds	.03283	.00296	None	.00690	.00061	None
27 July	Phosphorus, 40 pounds ...	.00126	.00034	None	None	None	None
27 July	Potassium, 150 pounds ...	.00043	None	None	None	None	None
27 July	None	None	None	None	.00030	None	None
30 July	Nitrogen, 40 pounds	.00489	.00134	None	.00551		None
30 July	Phosphorus, 20 pounds ...	.00059		None	None		None
30 July	Potassium, 100 pounds ...	.00093		None	.00050		None
30 July	None	Lost		None	None		None
6 Aug.	Nitrogen, 120 pounds	.02986		None	.03498		.00088
6 Aug.	Phosphorus, 60 pounds ...	None		None	None		None
6 Aug.	Potassium, 200 pounds ...	Trace		None	.00018		None
6 Aug.	None	None		None	Trace		None
9 Aug.	Nitrogen, 80 pounds	.02961		Trace	None		None
9 Aug.	Phosphorus, 40 pounds ...	None		None	None		None
9 Aug.	Potassium, 150 pounds ...	None		None	None		None
9 Aug.	None	None		None	.00018		None
12 Aug.	Nitrogen, 40 pounds	.00451		None	None		None
12 Aug.	Phosphorus, 20 pounds ...	.00046		None	None		None
12 Aug.	Potassium, 100 pounds ...	None		None	None		None
12 Aug.	None	.00023		None	Trace		None

These tables, taken together with the one giving the ammonic and proteid nitrogen, present some instructive features. Assuming that the nitrogen used by the plants is furnished wholly by the soil in the form of nitrates, which in our case is probably true, and referring to the tables giving the nitric nitrogen for the respective years, we see that we have no reason to believe that there was a less supply in 1915 than in 1913. The table entitled "Distribution of the Ni-

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trates in the First Foot and the Succeeding Three Feet of Soil in 1913 and 1915" shows plainly that the total amount in the top four feet of soil was not less in 1915 than in 1913, but it also shows that the distribution was quite different in the two years. This, however, should make but little difference, for reference to the tables giving the nitric nitrogen in the soil samples taken throughout the season to a depth of four feet, show that the fourth foot does not usually, even in 1915, when our soil was kept moist by a succession of moderate rains, contain any large quantity of nitric nitrogen. We consider this depth the limit of the feeding area of the wheat plant. But if this should be too great a depth to take under our conditions, and if the plants do not feed to a greater depth than three feet, this would not alter the statement made relative to the total supply of nitric nitrogen in the two years. Further, any question concerning the relative supply of nitric nitrogen which might apply to the check plots in the respective years, could scarcely apply to the plots to which we applied 120 pounds of nitric nitrogen per acre in three applications, made at intervals of approximately four weeks, with the purpose of maintaining an excessive supply of this form of nitrogen in the soil. The first application of 40 pounds of nitrogen per acre was harrowed in to a depth of from two to three inches. We had to depend upon the rain and irrigating water for the distribution of the succeeding applications. We made no attempt to follow the distribution of these 120 pounds of nitrogen through the soil. It might have been interesting if we had been able to do so and further to have determined what portion of it was utilized by the plant and how much of it was lost in the soil. We have, in our observations of the effects produced upon the plants, a basis for a very rough estimate of the relative effects of the quantities, 40, 80 and 120 pounds, applied to the different plots. This rough judgment is that 80 pounds, applied in two portions of 40 pounds each, produces on our soil, almost, if not altogether, as great effects as 120 pounds applied in three portions of 40 pounds each. The effects of 40 pounds, applied at the time of planting, produce quite as deep a color in the growing plants, and the limits of the area to which it has been applied are quite as definitely marked as those of 80 or 120 pounds. This statement does not hold in other respects, for we shall see that the effects of the larger applications are quite regularly bigger than those of the smaller applications. It does not seem probable that either the quantity of nitric nitrogen present in the two years, or the distribution of the same in the soil, varied enough to produce the differences in the nitrogen content of the plants which we actually find. The stems constitute approximately 65 percent of the total plant, and while the amount of nitrogen present is smaller than

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in the leaves, and the part played by the latter in the economy of the plant may be greater than that of the stem, still the general effects of the fertilizers and of the seasons may be quite clearly seen in this portion of the plant, so we will consider the stems only, whereby we sacrifice nothing of the truth and gain much in brevity.

In the samples of the stems taken in 1913 we see that the total nitrogen is increased by the application of nitrates, and while this increase is not proportional to the amounts applied to the different sections of land, it is true that up to the end of July the stems of those plants grown with the largest application of nitrates contain the highest percentage of nitrogen. This relation was no longer evident when the plants have become so nearly ripe that it was no longer possible to separate the stems and leaves. It has elsewhere been stated that the sheaths are, for the most part, taken with the stems.

The amount of total nitrogen in the stems during the season of 1915 is much smaller than in 1913, but those grown with the application of nitrates are uniformly higher than those grown without it. The total nitrogen in the stems in 1915 is roughly equal to three-fourths of that present in 1913. This is true of the nitrogen in the stems up to the end of July only; from this time till harvest the stems, with whatever leaves were left, in 1915, contain more nitrogen than they did in 1913, while the heads contained very much less nitrogen than in 1913. In other words, the nitrogen was not transferred from the stems and leaves to the heads in 1915 to the same extent that it was in 1913. The ripening period did not produce the changes taking place during this period in the same thorough manner in the former as in the latter season.

These facts divide our considerations in two parts. The first part brings us to the beginning of the ripening period, and the second consists of this period. This is a natural and common division, which we observed in writing Part I (Bulletin 208), but for entirely different reasons than now.

The facts that we have presented show that the effects of the nitric nitrogen applied to the plots are of the same character and persistent throughout the two very dissimilar seasons. The same is true of the phosphorus and potassium, but in so far as the nitrogen content of the plant may be relied upon as an indication, the composition of the plants were quite unlike, all parts examined, stems, leaves and heads, were richer in total and proteid nitrogen in 1913 than in 1915, without regard to the amount of this element in the form of nitric nitrogen at the disposal of the plant.

The effects of phosphorus and potassium are, as in 1913, so indefinite and irregular that the small variations observed are not en-

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titled to consideration. The plants from the three check plots show quite as great variations among themselves as we find between these and the phosphorus and potassium plots. It must be remembered, however, that there is no compelling reason why plants grown on three abutting check plots should be identical in composition, especially if our contention that differences in the supply of plant food produces differences in the composition of the plant, and we may anticipate a little by adding, if its seeds, too, be correct. We have shown by experiment what we all know, that soil varies in the amount of total and of nitric nitrogen from foot to foot. (See Part I (Bulletin 208) p. 26.) We have further given, in former publications on the subject of Fixation of Nitrogen In Our Colorado Soils, instances of very great variations of nitrates within a few feet, variations of hundreds or even thousands of parts per million. Identity of results cannot be expected, but larger and persistent differences, such as we find occurring in all of the series of plants presented in Part I, and in this one, are founded on something more than accident; they have some general and sufficient cause.

Further, while the effect of the nitric nitrogen is evident and persistent through the two seasons, the total nitrogen in the plants in 1915 is only about three-fourths of that present in 1913. In this statement we compare 32 samples in 1913 with 36 samples taken in 1915. As stated, the relative effects of the respective fertilizers are discernable throughout both series. The seasons were dissimilar and this difference would appear to be the direct cause of the differences in the nitrogen content up to the end of July, or during the vegetative period. The factor which caused this difference can not be the total amount of water supplied by way of the soil, for that applied by irrigation and rainfall during the two seasons was very nearly the same. This is on the assumption that all the rainfall reached the ground, which is not correct. But if the amount of water supplied by the soil had been different, other results would still compel us to eliminate this as the cause for the difference. It is fortunately the fact that some of our plots in 1913 received during the season 30 inches of water, whereas, in 1915, the total received was a little over 19 inches. The samples from these plots receiving 30 inches of water in 1913 contained as much nitrogen as the corresponding plots that received 19 inches, so that a difference of 11 inches of water applied to the soil made no difference in the amount of total nitrogen contained in the stems, which we have used as representative of the whole plant. The same is true of the proteid nitrogen, or, perhaps I should say, that the differences are so small and irregular that we cannot consider them in this work.

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These facts are in harmony with others obtained with the wheat berry grown with different quantities of water.

We are justified by the latter facts in going further and asserting that the time of the application of water to the soil, provided there be at all times a sufficient amount of water present, does not make the differences which we are considering. This statement contemplates the application of water to the soil up to within fifteen days of the harvest. These statements are, however, in anticipation of the discussion of the work done with the berry and not with the plant.

There are three facts left in the problem, the prevailing temperature, the application of the water to the plant, not to the soil, and the sunshine. While it may be true that the temperature affected our problem, it seems difficult to believe that a difference of a few degrees should make such a radical difference in the amount of the total nitrogen in the plant, especially as the mean temperature for July was 64.74 and for August 62.77, which includes a period from before blooming till the maturity of the plant.

I am not conversant with any data on the minimum energy requirements of the wheat plant that serves to aid me in a solution of this question, but until I obtain further light upon the question, I shall consider the heat energy at the disposal of the plant as fully adequate. If this view be correct, we have left but two factors, the application of the water to the plants in frequent light rains and the prevalent cloudiness of the season. The determining factor seems to be either a combination of these two, or one or the other of them. It is a fact that the plants were wet a great deal of the time either from rain or dew. I do not think that we, at any time during the season, collected a sample of dry plants, except near or after midday, and the plants were often wet throughout the day. This fact impresses itself upon me as of great importance in our problem. Had we had wet plants, as we did have, and at the same time our usual amount of sunshine, I imagine that things would have stood much worse with us than they did at the end of July, for the plants would certainly have been scalded, if no worse trouble had ensued.

I do not intend in any way to indicate that continued cloudiness is not a factor in this question, but at the present time I believe that the frequent light rains and consequent heavy dews which kept our plants dripping wet for so large a portion of each day, often all day long, was the more important factor of the two. I do not recall having seen any data on this point and have made no experiments myself to study the effects of such conditions.

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We have said nothing about the ripening period. The principal reason for this is, that in 1913 the transference of the nitrogen from the plant to the seed, or its elimination from the plant, went on till the total in the plant was reduced far below what it was during the vegetative period; this was not the case in 1915. The total nitrogen in the plant remained high and the amount in the head did not increase as it did in 1913. In 1913 the season was very favorable, in 1915 it was quite unfavorable for the maturing of a good crop. One result of the unfavorable crop season of 1915 was the development of rust on all three varieties of wheat grown, but it injured the Red Fife, whose composition we have given for two years, 1913 and 1915, perhaps the least of the three. The indications are that the normal processes in the wheat during the ripening period were seriously interfered with, and while the changes may have been normal in their general character, which admits of a doubt, they were at least incomplete. The severe attack of rust was a direct result of the weather conditions. It was fortunate for us that we had chosen the Red Fife for our study. Had we chosen Defiance we would have been unable to obtain any results that we would have felt willing to use, because the crop was ruined, especially on those plots to which sodic nitrate had been applied. That these plots were more susceptible than the others to attack by this fungus can scarcely admit of a doubt. We might express the reasons otherwise. The plants were large, succulent, badly lodged, almost continuously wet, and rusted. The other plots were very severely attacked, but they were not so severely, and the wheat yielded was better than that of the nitrate plots, though very far from good. The Red Fife is naturally several days earlier and probably more resistant to the effects of rust than the Defiance. It is from such considerations that we conclude that the course of the changes in the plant, including also the heads during the ripening period of 1915, was greatly interfered with by this fungus, and that this is the cause of the results obtained. The weather conditions, especially those features which kept the plants continuously wet, were accountable for the low nitrogen in the plants up to the end of July. But during the ripening period the immediate cause of abnormal development was the severely diseased condition of the plants, and the effects of the weather conditions proper are concealed by the effects of the rust.

The ammonic, amid and nitric nitrogen in the plants are considered of less importance in this question than the total and proteid nitrogen. The presence of nitric nitrogen in the wheat plant is probably altogether dependent upon an accidental excessive supply in the soil, while the ammonic and amid nitrogen are intermediate and transient forms in the plant. The proteid nitrogen, on the other

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hand, is presumably the end product of the transformations and while it may be transferred from one part of the plant to another by little-understood processes, it represents the most permanent form of nitrogen in the plant. It is, however, evident that the total nitrogen includes a very considerable amount of nitrogen in other forms; at the end of July only about 60 percent of the total nitrogen is present as proteid nitrogen, nitrogen precipitated by Stutzer's reagent, and at the end of the ripening period in a few cases as much as 70 percent. The latter figure was obtained in 1915, when both the total and proteid nitrogen in the plant were very high compared with the results obtained in 1913.

I have stated that the nitric nitrogen appearing in the wheat plant owes its presence to an excessive supply of this form of nitrogen in the soil, and is probably accidental. This statement is based upon the fact observed in all of the samples examined during the two years, i. e., that the plants grown with the application of sodic nitrate regularly contain some nitrogen in this form, while those grown without it contain either only a very small amount, or no nitric nitrogen at all. The table contains only the results of 1915 and none of those of 1913. At one time we thought that oxidation in the air-dried plant actually took place, but were unable to establish this, and now believe that any nitric nitrogen found, even in the dried plant, represents an unused excess originally derived from the soil. The method used in determining the nitric nitrogen in the plant may give us slightly low results, but it certainly does not give us high results, so I think that we can depend upon our results as corresponding to the facts, especially as we took 150 grams of the green plant, or an equivalent amount of the dried plant, for the determinations. We found no nitric nitrogen in the heads. The facts are, in the main, concordant with what is known regarding the occurrence of nitrates in wheat plants. Jost, in his Plant Physiology, p. 140, says "Tobacco, turnips, sunflowers, potatoes and wheat may be taken as examples of cultivated plants which contain large quantities of nitrates. In the last two the nitrate amounts to from 1.5 to 2.8 percent of the dry weight. * * * The maximum of nitrate is found in the root, less in the stem and leaf, none at all in the seed. The nitrate increases as the flowering period approaches and decreases when fruiting takes place. * * Such storing of nitrate, however, is by no means universal. Many plants absorb no more than they absolutely require." It will be noticed that the amounts that we have found in our samples, grown with the application of 120 pounds of nitric nitrogen per acre, are far below the quantity given by Jost. In summarizing the lecture from which the above quotation is taken, Jost says we have learned "that nitric acid is the chief source of nitrogen, and that that element in co-operation with carbohydrates goes to form proteid especially." (p. 145). To quote Jost again, Plant Physiology, p. 174: "Schultze assumed that the amino-acids first arising from the proteid substances, in addition to which perhaps

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also primarily asparagin and glutamin may arise, break down further into ammonia and form this, in presence of suitable carbohydrates—perhaps glucose—asparagin and glutamin are constructed. These amids would be thus, not the main products of decomposition, but rather the first stages in a higher synthesis and their formation from this point of view is not inconceivable. According to Hausteen's experiments the amino-acids appear—so far as they have been investigated—much less adapted to the formation of proteids than ammonia and the two amids above mentioned. * * * * This hypothesis of Schultze's which has been recently supported by Balicka-Iwanoska (1903), (and also by Prianischnikow, 1904 and earlier), appears to us to explain best the facts known to us at the present time in this difficult region of investigation. * * * *

"A new difficulty presents itself when we attempt to investigate how proteids arise from amino-acids and amids. It cannot be doubted that the process takes place in light and Pfeffer (1873) has further given proof that light acts indirectly in the process."

The nitrogenous material out of which the proteids are built is primarily nitric acid, the principal intermediate products are ammonia and the amids, and these may occur in our wheat samples in varying quantities according as their transformation into proteid is more or less complete. We observe that corresponding to this theory we find the nitric, ammonic, amid, proteid and also the total nitrogen highest in those samples grown with the application of nitrates, which we used in liberal quantities for the purpose of discovering if possible the specific effects of nitric nitrogen, especially upon the character of the kernels produced.

THE ASH CONSTITUENTS OF THE PLANTS

We have not repeated the work of 1913 on this subject except to determine the ash constituents in one set of samples of the whole plant taken 5 August, 1915. We gave one set of samples for Fife in Part I, taken 31 July. The plants at this date in 1913 were as mature, or perhaps rather more so, than plants of the same variety on 5 August, 1915. The results obtained with the 1913 samples present the effects of the fertilizers upon the ash constituents under favorable seasonal conditions. The results of 1915 will serve to show the same thing under unfavorable seasonal conditions, and in these particular cases also the character and extent of the changes that we may attribute to the weather conditions.

ASH CONSTITUENTS OF WHEAT PLANTS—CROP 1915

Red Fife	Ca.	Mg.	Fe.	Mn.	K.	Na.	P.	S.
Fertilizer per Acre	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.	Perct.
Nitrogen, 80 pounds	0.156	0.107	0.022	0.004	1.376	0.026	0.084	1.469
Phosphorus, 40 pounds	.116	.094	.007	.004	.868	.035	.058	1.527
Potassium, 150 pounds	.087	.0106	.012	.004	.980	.031	.061	1.627
None	.105	.073	.014	.004	.972	.041	.091	1.829

The sulphur and chlorine were not determined. These determinations were omitted also in the 1913 series.

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The above series, though consisting of fewer members than might be desirable, shows the same effects upon the relative amounts of the ash constituents as in 1913, when we analyzed 12 instead of 4 samples of straw as in 1915. The specific effects of the nitrate were to increase the calcium, potassium and magnesium and to depress the silicon; we see the same features in the above results. In 1913 it produced no appreciable effect upon the amount of phosphorus. The check plot was of course adopted as our standard. In the results of 1913, we observed that the application of phosphorus and also that of potassium tended to depress the phosphorus in the plant. We observe the same tendency in 1915. While the nitrate depressed the silicon, it increased the potassium, calcium and, in a less degree, the magnesium. The net result, however, was to increase the ash. The increase in 1915 is very slight, so slight that one can scarcely claim it to be satisfactorily decisive. If we compare the amount of these constituents for the two years, we will find it from 0.340 to 1.0 percent lower in each of the four samples than in 1913. On looking at the individual constituents we observe that the potassium suffers approximately one-third of this depression, though all of the ash constituents participate in it.

The weather conditions have already been given in some detail. It has been stated that the plants were kept wet a great portion of the time. Whether this is the cause of the lower ash constituent or not, it is a fact and seems to me the probable cause.

In considering the nitrogen compounds in the plants we had two series of effects, one of which we attributed to the fertilizers and which was consistent throughout the two seasons. The other we attributed to the weather conditions. In addition to these two series of results, which seemed to run parallel up to the end of July, we had a third series of results which was not consistent at all for the series of samples taken after 30 July in the respective years. These results I believe to have been effected by the action of the rust. The results obtained by the study of the ash constituents of the plants in the two years are in harmony with those obtained by that of the nitrogen compounds up to the end of July, the latest date to which our work on the ash constituents can be applied.

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SUMMARY

The summary includes the facts presented in Part I, with which no summary was presented, because we intended to record the results of another season's work on the subject dealt with before we formulated our conclusions.

We believe that the fundamental condition in this work is the question of food supplied by the soil; the weather conditions are important, but accidental.

The land used for these experiments contains a liberal supply of total potash. We found in 1913 that in the top two feet of soil there was 101.6 tons of this substance per acre, of which approximately one ton was available at that time. If, however, we base our estimate on the hydrochloric acid-soluble potash, we find that there was over 25 tons available. The citric acid, soluble phosphoric acid was about 1,400 pounds, that soluble in hydrochloric acid, 9,800. The total nitrogen found in the same depth of soil was 8,240 pounds. The amount of plant food was considered ample. This estimate, however, was based not entirely upon analytical results, but the crops produced by the land were also considered.

The nitrogen, while sufficient, was not considered remarkably high. It was shown that a very considerable portion of this nitrogen actually existed in the soil in the form of nitric nitrogen at the time of planting. The top two feet contained nitric nitrogen equivalent to 211 pounds of sodic nitrate. The biological conditions of the soil are such that the conversion of the soil nitrogen into nitric nitrogen proceeds rapidly.

The power of this soil to fix nitrogen has been discussed in previous publications (Headden, Bulletin 178, p. 89; Sackett, Bulletin 179, p. 29), in which it is shown that this factor is a very important one, being sufficient to add very considerable quantities of nitrogen to the soil annually, provided the conditions be reasonably favorable. I may emphasize this fact by giving the results of observations made on a sample of soil from this tract of land, but not from either of the three sections used for these wheat experiments. The sample was kept in a large bottle, loosely corked, at the temperature of the laboratory. There was no opportunity for the soil to absorb ammonia or nitric fumes. This sample was put into the bottle just as it was brought from the field, except that the clumps were broken up and the soil made reasonably fine. In 27 days this soil gained 4.82 milligrams of nitrogen for each 100 grams of soil, or 48 parts per million. This soil had nothing added to it, nor was it treated in any way to facilitate this bacterial activity, except that it was kept in a moderately warm room. This was the smallest gain observed by myself or Prof. Sackett in samples of this soil. The other samples, however, were incubated and the moisture was

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brought up to about the optimum quantity. Even at this minimum rate of fixation, the amount of nitrogen added to the soil in one month would be sufficient, if nitrified, to nourish several crops of wheat. So it is by no means necessary that even this minimum observed rate of fixation should be maintained throughout the year in order that this process should form a factor demanding our consideration. This amount of fixation means the addition of 192.8 pounds of nitrogen to an acre-foot of soil in one month, equivalent to the addition of about 1,100 pounds of sodic nitrate. We have nowhere intimated that we hold this nitrogen to be available in this form, but have taken, tacitly it may be, the extreme view that only nitric nitrogen is available to the wheat plant.

It is because of the importance and immediate connection of this latter form of nitrogen, with the growth, yield and, as I believed when I began this work, with the character of the wheat produced, that we have given in some detail the moisture and nitric nitrogen in the soil throughout the two seasons of 1913 and 1915. The moisture is not only necessary to the growth of the wheat plant, but also to the biological factors in the soil. We determined the moisture in the soil for the latter reason quite as much as for the former, and endeavored to determine the effects of irrigation upon the distribution of the nitrates. In 1913, we found a very great difference in the amount of, and also in the distribution of, the nitrates on the different dates, 29 April, before irrigation, and on 27 June, thirteen days after irrigation. These differences were so big that the usual considerations of variability due to differences in samples from place to place within limited areas, are wholly excluded. In the top four feet of one sample we found on 29 April, nitric nitrogen equivalent to 1,908 pounds of sodic nitrate; in another on the same date, for the same depth of soil, the equivalent of 471 pounds; but in this latter sample we find in the 7th, 8th and 9th foot, taken together, the equivalent of 721 pounds. On 27 June, after irrigation, we found for the top four feet of three different sections of soil, 162, 91 and 156 pounds, respectively, and below the depth of four feet, usually from six to eight pounds per acre-foot; but this amount varies somewhat; the maximum found below four feet in three borings taken to a depth of 12 feet was 30 pounds to the acre-foot, the minimum was nil. In the cropped land the nitric nitrogen, especially during the actively vegetative period of the plants, usually falls to less than an equivalent of 20 pounds of sodic nitrate per acre-foot of soil, except in the top three or perhaps six inches, where it is usually a little higher, provided the sample be not taken immediately after a rain. The surface portions of land cropped to wheat may occasionally show nitric nitrogen equivalent to as much as 200 pounds of sodic nitrate to the acre-foot, but in most cases we found from 30 to 40 pounds in such samples. In 1913, the second

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foot seldom showed as much nitric nitrogen as would be equivalent to 20 pounds of sodic nitrate per acre-foot. This was a season of high rainfall in general, and long periods without any. In 1915, with twice the total rainfall, which fell in a succession of light rains well distributed throughout the season, we have a very different distribution of the nitric nitrogen, for we find even the fourth foot containing, at the end of June, as high as the equivalent of 48 pounds of sodic nitrate; but by 3 August, the nitric nitrogen had been used up to such an extent, that the surface foot contained the equivalent of only about 20 pounds of sodic nitrate; the minimum found in the fourth foot at this time was nil. The nitric nitrogen had disappeared from all of the plots in the same manner and to about the same extent. The amount of nitric nitrogen in the top four feet of soil was at all times throughout the season larger in 1915 than in 1913. This fact was due, in all probability, to the different distribution of the moisture. The period of minimum nitrates in the soil was, in 1915, 3 August, or the beginning of the ripening of the grain. The effects of the crop upon the nitric nitrogen in the soil were checked by cutting out the wheat on a small section 20 by 20 feet, and keeping it fallow throughout the season. Samples were taken from this fallow ground, and also from that occupied by the wheat plants on 3 August, 1915, to a depth of four feet. The nitric nitrogen present in this fallow land to this depth was equivalent to 285.5 pounds of sodic nitrate; that present in the cropped land, to the same depth, was equivalent to 46.9 pounds of sodic nitrate. The crop, either by preventing the formation of the nitrates, or by using them up, had made a difference equal to 238.6 pounds of sodic nitrate in this depth of soil.

It was shown in Bulletin 178, p. 91, and again by Sackett in Bulletin 193, sample No. 75, pp. 24 and 39, that the nitrifying efficiency of this soil is relatively high. In Part I (Bulletin 208), pp. 20 and 21, I showed the differences in the amount of nitric nitrogen in land cultivated fallow during the season, and in that cropped to spring wheat, for samples taken on 4 December, 1914. I also gave the amount of nitric nitrogen found in the cropped land on 1 August, 1913. The average given by three sets of samples, each composed of eighteen sub-samples, taken to a depth of nineteen inches, corresponds to 542.43 pounds of sodic nitrate per acre for the fallowed land. The nitric nitrogen found in one of our check plots of Defiance wheat on 1 August, 1913, taken to a depth of two feet, corresponded to 101.20 pounds sodic nitrate per acre. This same plot was cropped to wheat in 1914, the wheat was harvested 6 August, the land irrigated 28 August, plowed 14 November, and sampled on 4 December. We found as the average of two sets of composite samples taken to a depth of nineteen inches, the equivalent of 299.35 pounds sodic nitrate per acre. While the value

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of these figures is lessened by the fact that the sample representing the nitric nitrogen present just before harvest was taken in 1913, and the other two in 1914, they still serve to give us a very definite idea of the rate at which the nitric nitrogen is restored to this land after previous removal by a crop, for we can safely assume that the crop of 1914 reduced the nitric nitrogen present at harvest time, 1914, to approximately the same amount that the crop of 1913 had reduced it the previous year. The difference between the amounts of nitric nitrogen in the fallow land and the cropped land on 4 December, 1914, gives us the difference of nitric nitrogen in favor of the fallowed land. This difference is equal to 243 pounds of sodic nitrate. The difference between 299.35 and 101.20 gives us an approximation to the difference in the amount of nitric nitrogen in the top two feet of soil on 1 August and 4 December; this difference is equivalent to 198 pounds of sodic nitrate.

This question was followed more closely in 1915 than in 1913, with equally positive results. The cropped land again contained its minimum amount of nitric nitrogen about 1 August. On 3 August, Section 1800 Red Fife, Check Plot, contained in the surface foot the equivalent of 29.3 pounds of sodic nitrate, on 30 August 42.2, on 22 November 89.1, on 14 December 103 pounds; Section 1900, Red Fife, Check Plot, contained: On 3 August 19.5 pounds, 30 August 50.6, 22 November 73.6, 14 December 121.8. An extended statement of these results is given in tabulated form on a previous page, in which the amount of sodic nitrate corresponding to the nitric nitrogen found is given both for the surface foot and also for the succeeding three feet. This table also exhibits the rapid fall of the nitric nitrogen in the cropped land from the middle of May till the beginning of August, namely, during the growing period of the plant.

The total nitrogen was determined at various times during both seasons. The results for 1913 are given on pages 15, 19 and 23 of Part I, and for 1915 on page 18 of this bulletin. I think it very unsafe to attempt any interpretation of the results, owing principally to the difficulty of obtaining samples of soil which will vary by less than the amounts of nitrogen here concerned; for instance, an actual increase of ten parts per million in any month would mean a percentage difference of one one-thousandth, but this would mean, if converted into sodic nitrate or calculated as proteid matter, 240 pounds for each four million pounds of soil. We sampled 150 square feet of soil, taking a core from the center of each square foot to a depth of one foot, and it was rarely the case that contiguoue square feet of soil showed so small a difference in total nitrogen as 0.001 percent. On the other hand, this difference actually reached 0.0354 percent, or more than 35 times as much as would have a very considerable significance in the development of the crop if

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present in the form of nitric nitrogen. It is for this reason that I have preferred to state the fixing power of this soil as found by laboratory experiments.

We have not been able, up to the present, to follow the study of the bacteriology of this soil further than was given in Part I.

The study of the composition of the plant, and the effects of the fertilizers, have been presented, together with a general statement of the weather conditions for the two seasons.

One of the first, important questions in our study, especially under our conditions, is: What is the effect of different amounts of water applied to the soil? Others have studied this question in relation to the production of dry matter, but not, so far as I know, as touching the composition of the plant. This question is important in our study, but is incidental to it, for this reason we have prosecuted it only so far as seemed advisable to determine its influence in a general way. We found no differences in the amount of nitrogenous compounds in the plants that could be attributed to the varying amounts of water applied.

This statement is based on two series of samples which have received 31 inches of water in all, 24 inches irrigation and 6.77 inches rainfall, compared with 16 series grown with 19 inches of of water, 12 inches irrigation and 6.77 inches rainfall. I am speaking of the plant at this time, but I shall present the effect of different quantities of water applied to the soil on the composition of the kernels, at another time. This question was presented in another form in 1915, when a series of light rains, amounting to about 13 inches during the growing season, kept the plants wet a great portion of the time and further caused very heavy dews, so that the plants, not the soil, were thoroughly wet by application of water almost daily. The amount of water received by the crop in the two seasons was essentially the same, about 19 inches, but the effects which seem attributable to water, or more accurately stated, to the manner of its application in 1915, are very marked. For the present it may suffice to state that it caused the principal differences in the composition of the plants up to the end of July, at which period another factor, largely the result of this external moisture, began to play a still more important part. This factor was the abundant development of rust. These conditions were unfortunate so far as the size of the crop was concerned, but fortunate for the purpose of our study, though we did not desire to introduce these factors into our problem. The general effect was to suppress all forms of nitrogen present in the plant throughout its growing period, and the same was true of the ash constituents. It seems almost as though this externally applied water had actually caused a leaching out of the very substance of the plant. This does not seem so improbable, especially in regard to the ash constituents, when it is

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recalled that it is shown in Part I, p. 42, that 93 percent of the total soluble ash in the air-dried wheat plant can be extracted with water. The size of the plants and the percentage of dry matter in them was not materially different in the two seasons.

The part played by the greater cloudiness and a lower mean temperature in 1915 than in 1913 has not been made out. It is for this reason that I refer to effects that seem attributable to water, or its manner of application in 1915. At the present time, I entertain almost no doubt but that these effects are due to the external application of the water to the plants, or to their having been kept wet for so large a portion of their growing period. There are but two other things that I see, in addition to the cloudiness and mean temperature, that may militate against this view, and they are, the extent to which a living plant may differ from a dead one in the solubility of its constituents, and the possibility that transpiration was retarded to a sufficient extent to have reduced the intake of nitric acid and the non-volatile ash constituents.

The very different weather conditions which prevailed during the two seasons were in reality very fortunate for us, for they served to demonstrate the fact that the observed effects of the fertliizers applied in 1913 are independent of the weather. The weather conditions of 1915 made great differences in both the nitrogen compounds and ash constituents of the plants, but they did not obscure the effects of the nitrate applied upon the total or the proteid nitrogen or the silicon or the ash constituents in general. The same is true in regard to the effects of the phosphorus and the potassium.

The effects of the application of nitrogen was to increase the nitrogen in all parts of the plant; this was uniformly true in the stems, leaves and heads, for both the total and proteid nitrogen, and as positive in the wet season as in the dry one. It increased it in the stems and leaves and less regularly so in the heads. It lowered the percentage of dry matter; it lowered the percentage of silicon; it increased the percentage of potassium, calcium and magnesium as a rule, and increased the total ash, while it exerted no influence upon the amount of phosphorus in the plant. It increased the height of the plant, the length of the head, and the color of the plant, but it did not increase the kernels per spikelet.

Phosphorus seemed to be either indifferent to, or possibly tended to depress, the amount of nitrogen in the different parts of the plant. The same is true of potassium, with a stronger tendency to depress the nitrogen.

Both phosphorus and potassium depressed the phosphorus in the plant. This is true of these elements except in one case, in 1913, in which the plants grown with the application of potassium, contained more phosphorus than those grown on the check plot.

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These effects upon the composition of the plant are not changed by the weather conditions. In Colorado Bulletin 205, I pointed out a marked effect produced upon the physical properties of the kernels by the application of nitrogen in the form of sodic nitrate, namely, that it produced flinty and often shrunken kernels. This effect was not changed in our wet season of 1915. Further, we cannot see that the yellow-berry question was materially affected by the weather conditions of 1915 compared with those of 1913.

The attack of rust seemed to materially affect the course of the chemical changes that took place after the early part of August, 1915, compared with those that took place during the ripening period of the plant in 1913.

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A BACTERIAL STEM BLIGHT OF FIELD AND GARDEN PEAS

BY
WALTER G. SACKETT

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A BACTERIAL STEM BLIGHT OF FIELD AND GARDEN PEAS

By WALTER G. SACKETT

INTRODUCTION

Before the introduction of alfalfa into the San Luis Valley, field peas were grown very extensively as a leguminous crop for feeding purposes. Aside from their value in this role, their use in a crop rotation as a means of restoring partially the soil fertility lost by excessive and continuous cropping with small grains, was soon recognized.

For a number of years peas were used almost exclusively as the forage crop, and the acreage planted was very considerable; however, some five or six years ago. it was found that alfalfa could be grown successfully nearly everywhere in the valley. It succeeded very well for the first two or three years, but in 1914, following a heavy, late spring frost, the crop was attacked by the bacterial stem blight which reduced the tonnage of the first cutting 60 to 80 percent, to say nothing of the injury resulting to the plants themselves. Since then there has been a recurrence of the disease each year with varying degrees of severity. Quite naturally, with the appearance of this new trouble, the feeders may have to turn their attention more largely to field peas, but let us hope not to the exclusion of alfalfa.

Practically all of the cultivated land in the San Luis Valley lies at an elevation of between 7,500 and 8,500 feet, and at this altitude the temperature usually remains cool until well into the summer; frosts may be expected any month of the year. The soil is a sandy loam for the most part, and there is an abundance of irrigating water.

The pea being a lover of cool soil and cool weather, it is difficult to conceive of a location where conditions are better adapted to pea growing than in this old lake basin. For years they have been raised here to perfection without the first complaint of anything in the way of a bacterial, fungous or animal pest. But it is a long road that has no turning, for in the spring of 1915 the peas over almost the entire valley, which includes some 500,000 acres, were attacked by a disease, previously unknown in the community, and which at the time threatened to be even more serious than the alfalfa blight.

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At about the same time that complaints were received of this trouble on field peas, a similar blight made its appearance on garden peas in Northern Colorado.

In the pages which follow, will be found a description of this disease and of the microorganism which has been found to be responsible for the trouble.

HISTORY AND DISTRIBUTION

The first occurrence of the disease was noted by Mr. E. H. Thomas, county agent for the San Luis Valley, on May 27, 1915, in the garden of Mr. Wm. Ollinger, Hooper, Colorado. In this instance, garden peas for family use had been planted in soil which had been very heavily manured, and when the vines were 3 to 6 inches high, they began to turn brown, dry up and die. The owner attributed the trouble to too much manure or to excessive alkali. However, Mr. Thomas was inclined to look upon these facts as of secondary importance, and accordingly sent the writer several specimens of affected peas at this time.

The general appearance of the plants, with their characteristic bruised, water-soaked leaves and stems, suggested, at first sight, bacteria as a very probable cause of the trouble, and subsequent experiments have confirmed this supposition.

The next locality where the disease was observed was in Blanca, where, on June 1, 1915, Mr. Thomas found the same trouble attacking field peas; during the next few days he noted the blight in the vicinity of San Acacio, Antonito, Monte Vista and Center. In fact, we are reasonably safe in saying that it was general on the early planted peas over practically the entire valley.

The writer visited the localities mentioned above on June 3 and 4. The peas varied considerably in size, ranging from 3 inches in height to 8 or 10, and in the two days that we spent in looking over the fields, we did not find more than two or three tracts that were entirely free from the trouble. The severity of the attack appeared to differ in the different localities, due possibly to the fact that the infection had progressed more rapidly and was farther advanced in some places than in others; now and then we came across a field where only an occasional plant was affected, but again there were many where it was almost impossible to find a healthy one.

Mr. Thomas visited one of the worst affected fields at Antonito on July 22nd. From the roadside, there appeared to be a full stand of good vines, but upon closer examination it was found that at least one-third of the plants were missing. The average branching of the remaining plants was heavier than normal, there being many with three or more vines, while under ordinary conditions only two would have been present. The old infection had dis-

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appeared with the death of the first shoots, and the present crop was largely new growth. The vines were heavily podded and thrifty.

Mr. Thomas also visited a number of fields in the vicinity of Blanca and San Acacio on July 21, 1915. On sandy soil where the supply of moisture was limited, the peas had suffered heavily from blight. In two fields in particular, where the crop was planted on new ground, the disease destroyed fully three-fourths of the plants, but in the same locality on practically the same kind of soil where plenty of moisture was present, especially where an irrigation had been given shortly after the blight appeared, a large majority of the plants either threw out new branches, or, where they were not too badly infected, continued their growth.

The first isolations of the causal organism were made from material collected at Antonito on June 4, 1915.

VARIETIES OF FIELD PEAS

The two varieties of field peas that are planted most extensively in the San Luis Valley are the native White Mexican and the Warshauer.

The Mexican is probably a mixture of Canadian Beauty and Golden Vine with French Grey and possibly a few Early Britain.

The Warshauer is a white pea that has been developed by the Warshauer-McClure Sheep Company. of Antonito, Colorado, by hand picking from peas that were two weeks earlier than the common Mexican. It is supposed that the seed originally planted, when this selection was made, was one of the garden sorts usually considered as, "Earliest and Best". However, the pea has been reared under field conditions and continually hand picked until the Warshauer pea is now a decidedly fixed type. It is a medium-vined early pea which begins to blossom when 6 to 8 inches high, resulting in a good distribution of pods thruout the entire length of the vine.

On June 15, 1915, we received a letter from the Empson Packing Company, of Longmont, Colorado, stating that they were sending us some pea vines which appeared to be attacked by a blight. They said further that nothing of the kind had ever occurred before in the history of their canning business, and that altho the first traces had been noted only three or four days previously, the trouble was spreading rapidly. Already a number of fields were affected, and no little alarm was expressed over the possible outcome.

This outbreak of the disease on garden peas, contemporaneous with that on field peas in an entirely different part of the State.

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more than 300 miles distant and at an altitude 2,500 feet lower, was of more than passing interest. This led the writer to visit the Longmont section on June 21, in company with Mr. H. J. Cains, of the Empson Company. We found the garden peas affected in the same identical manner as the field peas in the San Luis Valley.

One field of about 12 acres was in very bad condition. The attack was well advanced and general; the vines were watery, olive-green to black in color; many were entirely destroyed, their growing tips curled and dead; others were green and in blossom, while some bore small pods. It was practically impossible to find a perfectly healthy plant in the whole 12 acres. The crop of shelled peas from this field was estimated at 50 percent. This same land was in peas the preceding year, but no disease was observed.

The blight was present, but to a lesser degree, in an adjoining tract of approximately the same size. In both cases the Alaska pea had been planted, the sowings having been made between the 15th and 20th of April.

A few infected plants were found in each of two other fields of the same variety of a somewhat later sowing.

A careful examination was made of several other Alaska plantings which were sown from ten days to two weeks later than any of the above, but in no instance did we find any of the trouble.

In addition to the Alaska, which is the earliest pea planted by the Empson Packing Company, two later sorts are grown for canning purposes. A diligent search for the disease on these later varieties failed to show even a trace.

A number of gardens in Fort Collins experienced a mild attack of blight on the early peas, but in no case was it sufficiently serious to cause any appreciable loss to the crop.

From these observations of one season only, it appears that so far as garden peas are concerned, only the earliest plantings of the early varieties are affected, and that the later sorts are practically free from the trouble.

We have endeavored to ascertain information regarding the distribution of the disease in the Western States, from the respective experiment stations, and up to the present time it has not been observed in Kansas, Montana, Wyoming, Nevada, Idaho, Arizona, or New Mexico. Professor J. J. Thornbee, of the Arizona Station, recalls having seen such a disease in both Nebraska and South Dakota. Professor G. R. Hill, of the Utah Station, reports the trouble as occurring in 1914 at Riverdale, Utah. Professor F. D. Heald, of the Washington Station, has recorded a bacteriosis of peas which may be the same as the Colorado malady. He has very kindly submitted pressed specimens for our examina-

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tion, and while it is difficult to reach any definite conclusions from dried material, I am inclined to believe that the Washington disease is different from that which occurs locally.

DESCRIPTION OF THE DISEASE

The disease can be recognized very readily by the watery, olive-green to olive-brown color of the stems, and by the yellowish, bruised and watery appearing stipules and leaflets.

When the blight makes its appearance early in the season, before the plants are more than 8 to 10 centimeters high (3 to 4 inches), one usually finds the stand very uneven and scattering. It is not uncommon to see 4 to 6 feet of drill-row apparently without a single plant, but a closer examination of the ground will reveal the brown and withered remains of what were once small pea vines. Here and there may be located a few stragglers that have not yet succumbed; they usually have several dead leaves next to the ground, while above these are four or five that appear bruised, watery and often ochre-yellow in color. (Right-hand figure in colored plate.) This leaf description applies particularly to the large, clasping stipules, the leaf-like structures at the base of the leaf stalk. (Left-hand figure in colored plate.) The stems of such plants are almost always dark-brown or black and considerably shrivelled, and so far as any further growth is concerned, they are practically dead. Occasionally one meets with a young plant of this kind in which the stem is black next to the ground, but above which both the stem and leaves are normal in color and look perfectly healthy.

In older plants, say 12 to 15 centimeters high, (5 to 6 inches) where infection appears to have taken place at a later period, the stem is watery, olive-green to olive-brown in color (middle figure colored plate); the petioles of the leaves attached to the diseased portion soon become involved, turn watery, olive-green in color, seem to wilt or collapse and allow the leaves to droop; the leaf blades and stipules subsequently appear bruised and watery along the veins and mid-rib, which condition is communicated to the leaf tissue proper, and the whole leaf structure turns a watery, ochre-yellow color, wilts and dies, shrivelled and brown.

So far as our present knowledge goes, the root and that part of the stem which is below ground are not affected.

The infection starts in most cases from 2.5 to 3 centimeters (1 to 1.25 inches) above the ground line and seems to move up the stem toward the growing tip. This is evident from the facts both that the discoloration on the lower part of the vine is nearly always darker than that higher up, indicating an older lesion, and that the lower leaves are the first to die.

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Under ordinary field conditions, a single pea plant branches at its base to form two or three principal vines. If the blight attacks and destroys one or more of these, the plant will usually throw out from three to five new ones, from the region below the diseased area, providing sufficient vitality remains to promote this growth. As a matter of fact, this is usually what takes place in the field, and, as a rule, the new growth progresses unmolested, altho, occasionally, this too is attacked. The secondary shoots are often small, and do not make the rank and vigorous growth that is characteristic of the earlier ones.

If the vines become diseased when they are small, and the main vine dies before branching has taken place, the chances are that no branches will be formed, and the plant will be killed outright. Sometimes even the older plants behave in this manner.

The leaves may develop the disease independently of any other structure and die before the stems show any trace of the trouble.

Very rarely small droplets of a pale yellow exudate are found on the stems.

The close resemblance in the appearance of alfalfa plants affected with the bacterial stem blight and that of diseased pea vines is a matter of considerable interest. In fact, the symptoms of the disease in the two plants are so similar as to justify one in making the conjecture that it is all one malady, and that one and the same causal agent is responsible for this condition. The pea and the alfalfa, both being legumes, and both grown in the same soil, under the same climatic conditions, and in a locality where the alfalfa blight has been very severe, the natural inference would be that both plants were suffering from the same cause. This is not the case, however, since the organism which we have isolated from the diseased pea vines and which we have been able to show is the specific cause of the pea trouble, is a separate and distinct form differing both morphologically and culturally from *Ps. medicaginis*. the alfalfa blight organism.

If fragments of the watery, olive-green tissue from either stem, leaf or petiole are mounted in a drop of water on a glass slide, there soon appears about the specimen a milky cloud easily visible to the naked eye. Under the low power of the microscope this resolves itself into a finely granular mass which flows out in all directions in long streamers, so characteristic of infections of this sort. Under the high power, the microorganisms which make up the milky cloud are readily distinguishable as moderately motile rods from two to four times as long as broad.

HISTOLOGY OF THE DISEASED TISSUE

Celloidin sections of diseased stems, killed in absolute alcohol. show the substomatal chambers to be packed with bacteria and

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many of the surrounding cells of the underlying parenchyma to be filled likewise. (Fig. I.) The infection appears not to extend into the medullar parenchyma, stereome, or vascular bundles. Neither in the field nor when artifically inoculated in the greenhouse, have we observed the vines, as a whole, to wilt; however it is not uncommon to see the petioles and leaflets in this condition. Frequently plants that have been inoculated artificially show a gradual wilting, or perhaps better designated as withering, in two or three weeks after infection, but not the sudden and complete

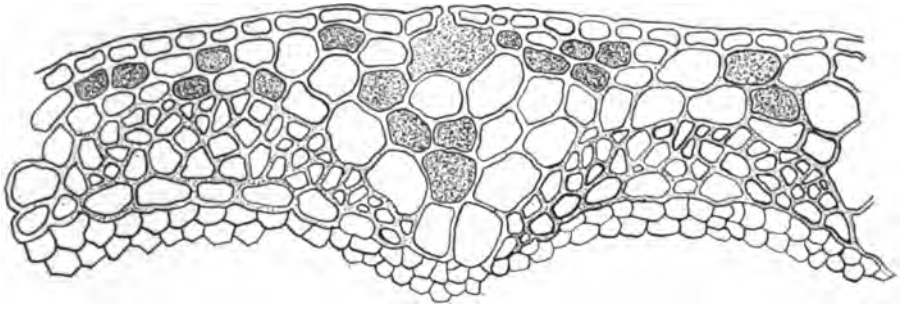

FIG. I

prostration of the entire structure such as is usually meant by the term *wilting* in the technical sense. Owing to the lack of satisfactory histological material, we are unable to say in the latter case whether or not there has been an actual invasion of the vascular system.

ISOLATION OF THE CAUSAL ORGANISM

The material from which the first isolations were made was collected at Antonito, Colorado, June 4, 1915. None of the tissue was given any preliminary sterilization previous to plating, but care was exercised not to use any that was clearly and unquestionably contaminated by soil or otherwise. Dilution plates were made June 5th in +10 nutrient agar, three plates being used in each case. These were incubated for 60 hours at 28° C., at the end of which time colonies were plainly visible.

ORIGINAL ISOLATIONS FROM FIELD MATERIAL, JUNE 5, 1915

No. 1. Stem.—A recent infection; tissue bright and fresh appearing, but watery and discolored well up on the stem; thin transverse section used for plating taken from near growing tip where disease was just developing. Colonies appeared in 60 hours; grayish white by reflected light, bluish cast by transmitted light.

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glistening, raised, structure appears flocculent under hand lens, gyrose under low power, margin undulating, general outline of colony round. Plates pure. Two colonies picked up on agar slants.

No. 2. Petiole from Stem No. 1.—Petiole taken from part of stem where disease was advanced, tissue dark and watery; section 0.5 mm. long, near juncture with stem, removed for plating. Colonies visible in 60 hours; same as those obtained from No. 1, but first two plates contaminated, third plate pure. Made subcultures from two typical colonies.

No. 3. Petiole from Stem No. 1.—Petiole taken from part of stem where disease was just appearing; tissue watery and olive-green in color. Colonies appeared in 60 hours; same as obtained from No. 1; culture pure in second and third plates. Made cultures from two typical colonies on nutrient agar.

No. 4. Leaf Blade from Petiole No. 3.—Material used in plating taken from dark, watery part of leaf blade next to mid-rib; leaf well up on plant and clean. Colonies appeared in 60 hours; same as preceding; pure in second and third plates. Picked up two characteristic colonies.

No. 5. Stem.—Recent infection; tissue light olive-green and watery. Colonies appeared in 60 hours; same as in preceding isolations; plates pure. Picked up two typical colonies on agar slants.

INOCULATION AND REISOLATION EXPERIMENTS

PEAS

September 21, 1915.—Four varieties of peas were used at this time: Warshauer, Horsford, Alaska and Wellington. The plants were grown in 5-inch pots, one variety to a pot, and were fourteen days old when inoculated.

A 24-hour agar culture of the organism that was isolated from Stem No. 1 was used in this series; the agar growth was worked up in the water of condensation at the bottom of the slant, and the suspension thus obtained was employed as the inoculum. The stems to be inoculated were first scarified lightly with a sterilized scalpel until the surface was slightly moist, and then several loop-fulls of the culture were spread over the prepared spot, 1 to 2 centimeters in length. Following this, the culture was pricked into the tissue with a sterilized needle. Three to four scarifications, 2 to 3 centimeters apart, were usually made on each plant, and one plant thus treated was left in each pot uninoculated for a check. They were sprayed immediately after infection with sterile, distilled

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water from an atomizer, and placed under bell jars in subdued north light in the laboratory. The bell jars were removed after 48 hours, but spraying was continued for three days more. On September 27, the plants were taken out-of-doors and left in bright sunshine. The inoculated areas on all plants appeared watery and olive-green in color, as compared with the check four days after infection. By the end of six days, there was little change, except for a suggestion of a watery zone beyond the edge of the scarified areas; the Wellington peas remained unchanged.

When observed on October 5, the watery zone had spread about 4 mm. beyond the scarifications, in all except the Wellington, and tissue removed from this part of the stem swarmed with bacteria when examined under the microscope.

By October 7, all varieties, except the Wellington, had developed the disease without question. It had now spread to the stipules, giving them a watery appearance, and in some cases, had produced a yellowing along the veins just as under field conditions. One leaf, that had been inoculated by a needle prick, had developed a large yellow blotch, such as occur in the field. The yellow, olive-green color and watery character had spread along the stem some distance from the original scar. We had had two hard frosts on the 5th and 7th of October, and the plants had been exposed to both.

October 12, 1916.—After two more heavy frosts, all of the plants were taken up, and a careful examination made. One of the most interesting points brought out in the experiment was the apparent lowering of frost resistance. Without exception, all of the plants in which the disease had made any progress succumbed to the frost and wilted, while every check and all of the Wellington plants stood up bright and fresh and showed no effects of the cold whatever. It would appear from this that the Wellington variety is more nearly immune than any of the others.

Observations October 12, 1915

Warshauer plants.—Check still green. Three plants were inoculated, and all show typical olive-green to brown discoloration. This is not confined to the inoculated areas, but has spread over the whole stem; vines somewhat shrivelled and tissue swarming with bacteria.

Horsford plants.—Check in good condition, still green and little affected by frost. Four plants were inoculated; before frost, the watery, olive-green color had spread over the stems irrespective of the original infection; after frost, the vines are shrivelled and brown, and bacteria are very abundant in the tissue.

Alaska plants.—Check normal. Three plants were inoculated; one has developed the disease in an unbroken lesion 12 centimeters

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long from the ground up; the others show the trouble just in the immediate region of the scar. In two of them, the infection has spread from the stem into the stipules, giving them a watery appearance which has become yellowish brown in the older lesions. The frost has shrivelled all the vines except the check. Bacteria abundant in affected tissue.

Wellington plants.—Four plants were inoculated with fourteen scarifications in all. As mentioned above, the frost seems not to have injured them appreciably. Almost no discoloration of the stems has occurred beyond the edge of the scarifications, and the vitality and general appearance of the plants are good. A little shrivelling has taken place where the inoculation was made, but there is no indication that the infection has spread. Bacteria are still present at the edges of the old lesions where the tissue appears darker and more watery, but none can be found in the scar proper. Apparently immune.

INOCULATIONS OF OCTOBER 19, 1915—PEAS

The plants of this series were inoculated by pricking (cluster of stabs) the culture into the stem with a sterilized needle without first scarifying the surface. A 24-hour agar culture of the organism isolated from Stem No. 1 was used. All plants were sprayed with sterile distilled water for four days after inoculation, and kept covered with bell jars for three days.

Observations

Warshauer.—Five plants inoculated, and one check. After four days stems begin to have watery appearance at point of infection; check normal in color. After twenty days, stems dark olive-brown and shrunken, leaves withered and brown, practically dead: check normal.

Horsford.—Four plants inoculated midway of the vine, toward the growing tip; one uninoculated check. After four days, sunken watery areas appear around the needle pricks; at the end of eight days, two of the plants are so badly shrunken and collapsed at points of inoculation as to allow the whole of the tips to droop. A microscopic examination of the watery tissue taken 1 cm. from needle prick shows the cells to be gorged with motile bacteria. The two remaining plants are watery and discolored, but have not collapsed. Check shows nothing of this shrivelling or discoloration. Causal organism reisolated from one of the two worst affected plants, q. v. page 18.

INOCULATIONS OF NOVEMBER 25, 1915.—HORSFORD PEAS

All of the inoculations heretofore were made with one of the cultures isolated from Stem No. 1 in June. In order to determine

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whether the remaining nine cultures, which were isolated at the same time, were likewise responsible for the disease and still virulent, each of nine Horsford plants was inoculated with a 48-hour agar culture of the respective organisms, to-wit: One from stem (No. 1), two from petiole (No. 2), two from petiole (No. 3), two from leaf blade (No. 4), two from stem (No. 5).

In this case, the bacteria were introduced into the stems by single shallow needle pricks about 1 centimeter apart and were distributed over the younger part of the vine. In addition to this, several leaves on each plant were punctured and the culture smeared over the injured leaf surface. All plants were sprayed with sterile, distilled water immediately after inoculation, covered with bell jars and placed in subdued light. They were sprayed again after 36 hours, and after 48 hours they were uncovered and placed in the greenhouse.

Observations

After four days, each of the inoculated plants shows a decided watery zone around each needle prick in the stem, and all of the leaf infections except the one made with culture from Stem No. 5 are taking perfectly; the leaves appear watery and bruised not only around the needle puncture, but also in isolated spots where the culture was rubbed over the surface; this suggests stomatal infection. The disease seems to be progressing most rapidly in the plant that was inoculated with one of the cultures isolated from the leaf blade. (No. 4.)

Dec. 1, 1915.—The watery, bruised appearance of the leaves is spreading and in some cases the leaves are beginning to curl.

Dec. 3, 1915.—The stem pricks now show up as sunken yellow areas, 3 mm. long.

Dec. 6, 1915.—Stems now dark olive-green and watery, not only around the needle pricks, but continuous over the entire stem where inoculated.

Dec. 7, 1915.—Reisolation made from plant inoculated with culture isolated from leaf blade q. v. page 18.

March 31, 1916.—All inoculated shoots brown and dead; four plants are entirely destroyed and have thrown out no new growth from below; one plant has two new shoots, while the remaining three have one each; none of these is vigorous, due possibly to other causes. Check normal.

INOCULATIONS OF DEC. 17, 1915.—HORSFORD PEAS

Nine different cultures, presumably all the same organism, picked up from colonies which were obtained by plating out tissue from a plant infected in the laboratory November 25 with a pure

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culture from a diseased leaf blade, were used in this experiment. Each of nine pea vines, approximately 15 centimeters in height, was inoculated with one of these cultures; the germs were introduced by needle pricks both in the stems and in the leaves. The plants were kept covered with bell jars for 48 hours and sprayed with sterile distilled water at frequent intervals; at the end of this time they were placed in the greenhouse.

Observations

Dec. 21, 1915.—All of the inoculations on the stems seem to have taken nicely, as they show watery, slightly sunken areas around the needle pricks.

Dec. 22, 1915.—The watery zone around the needle punctures more pronounced than the day before; many of the leaves are beginning to show watery spots.

Jan. 3, 1916.—While we are obtaining positive results unquestionably with all nine cultures, two of them seem to be somewhat more virulent than the others, as the disease is progressing more rapidly in the two plants inoculated with these particular strains. The watery spots encircling the needle punctures have coalesced into continuous dark olive-green lesions extending over the inoculated portion of the stems. All appear practically the same, but the area involved is considerably greater in the two cases mentioned above. Some of the leaves are shrivelled, others show watery spots and irregular yellow blotches; growth seems to be checked.

Jan. 31, 1916.—The inoculated shoots on all nine plants are dead and black; three of the plants have thrown out a single new shoot from below and three have responded with two new shoots; three died without producing any new growth at all. Fig. II is a photograph, taken at this time, of the two plants with the two new shoots; note in each case the dried, inoculated, dead vine between the two healthy ones. A third check plant is in the same pot.

INOCULATIONS OF JANUARY 6, 1916.—HORSFORD PEAS

The two cultures which appeared to be the most virulent in the preceding series, and which produced the most typical symptoms of disease in the host were selected for reinoculation in the present experiment. For convenience, these may be designated as Numbers 3 and 8.

Four plants, 7 cm. in height, were inoculated with Culture 3 by means of single needle pricks in a line along the stem. Three similar plants were likewise inoculated with Culture 8; 72-hour agar cultures were used in both cases. One check plant was left

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FIG. II

in the No. 3 pot. All plants were sprayed with sterile, distilled water, placed in greenhouse under bell jars and protected from bright sunlight by newspapers.

Observations

Jan. 7, 1916.—Sprayed plants; no indication of disease yet.

Jan. 10, 1916.—Removed bell jars and newspapers. All plants, except check, show watery, sunken zones around needle pricks.

Jan. 13, 1916.—The separate watery areas have now coalesced so that the stems exhibit a watery, bruised aspect over the entire section that was inocluated. Both cultures seem to be working equally well. Check still unchanged.

Jan. 24, 1916.—Three of the plants inoculated with Culture 3 are turning yellow and the tips of two are wilting, due apparently to collapsing and girdling of the stems, which are now dark

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olive-brown in color thruout their entire length; the fourth plant is reacting positively, but slowly.

Two of the plants inoculated with Culture 8 are still erect, but one is turning yellow and wilting, as described above; the stems of all the infected shoots are dark olive-brown in color.

Feb. 19, 1916. Culture 8.—One plant dead; one plant with inoculated shoot dead and two new shoots; one plant with inoculated shoot dark olive-brown and two new shoots.

Culture 3.—The inoculated shoots of all four plants dead. Three plants have two new shoots, and one has one new shoot.

INOCULATIONS OF FEBRUARY 19, 1916.—HORSFORD PEAS

Thirteen vigorously growing pea shoots about to blossom were inocluated with a 24-hour agar culture of Culture 3 by a line of single needle pricks; a fourth plant was pricked with a sterile needle as a control. The shoots were sprayed with sterile, distilled water and kept covered with a bell jar for 36 hours. When examined at the end of this time, watery zones were visible around each needle prick for more than 1 mm., while the check showed nothing but the hole left by the puncture.

Observations

After four days the watery areas surrounding adjacent punctures had coalesced to such an extent as to produce a solid infection over the whole stem. Control normal.

March 8, 1916.—One whole stem dark olive-green, and infection has spread over entire shoot; the disease has not spread as rapidly over second shoot, due possibly to the fact that the inoculation was in older tissue; third vine was accidentally broken off. Check normal.

March 31, 1916.—One plant, which was the less affected, has a black stem for 12 centimeters above ground, but it does not appear to be suffering particularly from the disease; it is growing, blossoming and seems vigorous. The inoculation in this case was on the lower part of the stem in rather old, hard tissue, and as has been observed repeatedly, infections in the older tissue do not have the same disastrous effects as when they are made in the younger. The second plant was inoculated a little higher up, and while in practically the same condition as the other, it is not as vigorous.

INOCULATIONS OF MARCH 9, 1916.—HORSFORD PEAS

To make certain that our stock culture of Culture 3 was remaining pure, it was replated March 4, 1916, and a new culture picked up from agar colony March 8.

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In order to verify the new culture, it was inoculated from a 24-hour agar streak into two pea vines that were in blossom. One shoot was pricked with a sterile needle for a check. All plants were in the same pot. They were sprayed as usual and covered with bell jar and newspaper for 48 hours. Placed in greenhouse.

Observations

March 13, 1916.—All inoculations are taking; sunken watery areas, 3 mm. in diameter, around each needle prick, and where these are close together the lesions have coalesced, making a continuous infection the entire length of the stem.

March 31, 1916.—Inoculated shoots dark olive-brown, watery, and shrivelled; discoloration and watery appearance extends from stems along mid-ribs of stipules, causing a partial wilting of the latter. Dark, watery spots also present on leaves and stipules, which suggest stomatal infection probably resulting from washing germs from inoculated stems onto leaves while watering. Both infected vines have a sickly, pale-yellow color and are partially wilted. The check plant shows infection in two spots where the culture has apparently dripped during watering.

April 14, 1914.—All shoots brown and dead, including check, from lowest point of inoculation out to the growing tip; lower part of vines green.

INOCULATIONS OF MARCH 23, 1914

The purpose of this series was to determine whether the organism which is responsible for the pea disease is likewise pathogenic for other common legumes. Twenty-four hour agar cultures were used in all of the infections. In addition to needle prick inoculations in the stems and leaves, the entire plants were sprayed with a suspension of the culture in physiological salt solution. Just previous to this operation, they were thoroly sprayed with distilled water and then with the culture, until the liquid dripped from the leaves. Our object in spraying with the culture was to determine whether the stomata might not serve as a channel of infection, as well as mechanical injuries. All plants were sprayed with distilled water at frequent intervals and kept covered with bell jars for 48 hours after inoculations.

Horsford Garden Pea.—After four days, characteristic watery, olive-green depressions appeared around the needle pricks. After six days, splendid stomatal infections, appearing as dark, watery, green spots, developed on the leaves which had not been subjected to mechanical injury. (Plate II, Fig. 1.)

Golden Wax Bean.—After four days, there appeared around the needle pricks on the bean pods, grayish brown patches, .95 mm.

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in diameter. Similar injury with a sterilized needle did not produce the same results. Inoculated stems and leaves were unchanged.

April 14, 1916.—The spots on the bean pod remained unchanged and there was no evidence of the disease in any other parts of the plants.

Alfalfa.—April 14, 1916.—The plants appeared to be entirely immune to the disease.

Sweet Clover.—April 14, 1916.—Entirely immune.

Crimson Clover.—April 14, 1916.—Entirely immune.

Mammoth Clover.—April 14, 1916.—Entirely immune.

Cow Pea.—April 14, 1916.—Entirely immune.

REISOLATION OF CAUSAL ORGANISMS FROM PLANTS INOCULATED WITH PURE CULTURES

First Reisolation, October 27, 1915

Platings in nutrient agar were made from sections taken from pea stems which had been inoculated October 19 with a pure culture from Stem No. 1 and which had developed the blight with all the typical symptoms. The tissue used came from two different parts of the vine where it appeared watery and olive-green in color some distance from the point of infection. No attempt was made to sterilize the surface of the stems from which this was taken, previous to plating. The plates gave a pure culture, and from the resulting colonies, eighteen were picked up on agar slants; ten of these were selected and reinoculated into Warshauer field peas November 15. Typical blight resulted in every case.

Second Reisolation, December 7. 1915

The plant from which the reisolation was made was inoculated November 25, 1915, with one of the cultures originally isolated from an infected leaf blade, June 4, 1915.

Two sets of plates were made from this plant, one from the stem and one from the base of a watery petiole where the disease was just starting. The stem was yellow, watery and sunken over the whole area of needle pricks, not only around them, but between, as well.

In all former isolations, no precautions were taken to sterilize the outside of the stems previous to plating out the tissue. However, in the present case it was wiped with alcoholic mercuric

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chloride, 1-1000, after which a section to be plated was removed with a sterile scalpel. It was next transferred to alcoholic mercuric chloride (1-1000) for 15 seconds, then washed in three changes of sterile, distilled water. From the distilled water it was transferred to a tube of nutrient broth where it was crushed, and dilution plates were made from the suspension thus obtained.

The second set of plates was made directly from the watery petiole without any previous sterilization.

Pure cultures of the original organism were obtained from both sets of plates in the second and third dilutions; the colonies in the first dilution were so numerous, that it was impossible to tell anything about their purity.

Three colonies were picked up from the first set of plates and six from the second, making nine pure cultures in all, of presumably the same organism.

On December 17, these were all inoculated into pea plants, as described before on page 13 with positive results.

DESCRIPTION OF THE CAUSAL ORGANISM

Pseudomonas pisi, n. sp.

History.—The microorganism herein described as the cause of a bacterial stem blight of field and garden peas, and to which the writer has given the name *Pseudomonas pisi*, n. sp., was isolated June 4, 1915, from the watery portion of a diseased leaf blade. It was grown upon +10 nutrient agar until November 25, 1915, when it was inoculated into a pea plant, where it produced all of the symptoms characteristic of the disease. On December 7, 1915, a reisolation of the organism was accomplished, and after replating to insure purity, it was again inoculated into peas on December 17, 1915, January 6, 1916, February 19, 1916, March 9, 1916, and March 23, 1916. In every case, positive results have been obtained. The culture which has been used in the following species description came from the same stock as that used in the plant inoculations of December 17.

I. MORPHOLOGY

1. VEGETATIVE CELLS.—As the organism occurs both on culture media and in the plant, it is a short rod with rounded ends, mostly single and in pairs (Plate I, Fig. 1), but occasionally in fours and sixes; filaments have been obtained from very young agar cultures 10 to 97 μ in length. (Plate I, Fig. 2.) The individual rods measure 1.11 to 3.28 μ long and .58 to .82 μ wide. The length of the majority is 2.26 μ and the width, .68 μ.

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2. ENDOSPORES.—No spores have been observed. Agar cultures 6 days and 48 days old were stained for spores both with Moller's stain and with Zeihl-Nielson carbol fuchsin, with negative results.

3. FLAGELLA.—The organism is motile by means of a single polar flagellum readily demonstrable in 18-hour agar cultures stained by Loeffler's method. According to Migula's classification, this places the organism in the genus, *Pseudomonas*.

4. CAPSULES.—No capsules could be demonstrated either by Welch's method or by that of Hiss.

5. ZOOGLOEA.—No zoogloea have been observed.

6. INVOLUTION FORMS.—None observed.

7. STAINING REACTIONS.—The germ stains readily with all of the ordinary aqueous stains. Both aqueous and carbol fuchsin bring out the coarsely granular protoplasm of the cell, together with what appear to be polar bodies. Loeffler's methylene blue shows nothing unusual altho at times there is a suggestion of irregular staining. Neisser's stain reveals neither polar bodies nor any special intracellular structures. It is Gram negative and is not acid fast. Neither starch nor glycogen were demonstrated. Both anilin-water genitan violet and anilin water fuchsin stain it readily.

II. CULTURAL FEATURES

1. AGAR STROKE.—*Growth* moderate in 24 hours; abundant in 4 days. *Form of growth*—filiform, margins irregular. *Elevation*—flat. *Lustre*—glistening. *Topography*—smooth. *Optical characters*—translucent. *Chromogenesis**—grayish white, Engine Color No. 13. *Odor*—decided, rotten cabbage. *Consistency*—butyrous. *Medium*—slightly greened.

2. POTATO.—*Growth*—moderate, persistent. *Form of growth*—filiform. *Elevation of growth*—slightly raised. *Topography*—smooth. *Odor*—absent. *Chromogenesis*—cream, orange yellow tint No. 2 in three days, Engine color No. 7 in five days (light orange). *Consistency*—waxy and slightly viscid. *Medium*—gray-brown in fourteen days.

3. LOEFFLER'S BLOOD SERUM.—*Stroke*—moderate in 72 hours. *Form*—filiform. *Elevation*—slightly convex. *Lustre*—glistening. *Topography*—smooth. *Chromogenesis*—pale yellow, Engine color 3a. No liquefaction. Medium unchanged.

*Color terms refer to Standard colored papers made by Milton Bradley Co., Springfield, Mass.

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4. GLYCERINE AGAR.—*Growth*—abundant. *Form of growth*—filiform. *Elevation of growth*—slightly raised. *Lustre*—glistening. *Optical characters*—translucent. *Topography*—smooth. *Chromogenesis*—grayish white, Engine color No. 13. *Odor*—soured peas. *Consistency*—butyrous. *Medium*—greened.

5. MANNITE AGAR.—*Growth*—scant, just sufficient to define line of inoculation. *Form of growth*—filiform. *Elevation*—slightly raised. *Lustre*—glistening. *Topography*—smooth. *Optical characters*—translucent. *Chromogenesis*—color of boiled starch. *Odor*—absent. *Consistency*—butyrous.

6. GELATIN STAB.—*Growth*—best at top. *Line of puncture*—filiform. *Liquefaction*—begins in 24 hours; crateriform in 48 hours, broad funnel-shaped in three days (Plate II, Fig. 2), stratiform in seven days. (Plate II, Fig. 3.) Depth of liquefaction in tube 10 mm. in diameter, evenly inoculated, at the end of 30 days at 20° C. was 33.0 mm. Liquefaction in tubes regular size, 150x16 mm. complete after 102 days. *Color* of medium unchanged.

7. NUTRIENT BROTH.—*Surface growth*—scum in five days which becomes heavy, flocculent growth in ten days; sinks on agitation. *Clouding*—strong, persistent, fluid turbid. *Odor*—decided, putrefactive. *Sediment*—scant, compact and finely granular.

8. PLAIN MILK. 28° C.—*Coagulation* delayed until the fourth or fifth day, when a soft, more or less flocculent, curd is formed. *Extrusion of whey* begins in four days. *Coagulum* is slowly peptonized, the digested portion or liquid becoming light yellowish green in color. *Peptonization* begins on fourth day, 82% being digested in 21 days, and is complete on the 52nd. Reaction, 1 d. + 12, 2 d. + 12, 4 d. + 12, 10 d. + 4, 20 d. — 4. *Consistency*—soft curd. *Lab ferment* present.

20° C.—*Coagulation* delayed until the sixth or seventh day, when a soft curd is formed. *Extrusion of whey* begins in seven or eight days. *Coagulum* is slowly peptonized, the liquefied portion becoming pale lumuire green* in color. *Peptonization* begins on the eighth day, 60% of this curd being digested in 21 days and is not quite complete after 58 days. One-hundred c.c. portions in 200 c.c. Erlenmeyer flasks were completely peptonized in 28 days. Reaction 1 d. + 12, 2 d. + 12, 4 d. + 12, 10 d. + 4, 20 d. † *Consistency*—soft curd. *Lab ferment* present.

9. LITMUS MILK. 28° C.—Lavender-colored litmus milk begins to turn blue from the surface downward, becoming lighter

*Color Standards and Color Nomenclature—Ridgway.

†The development of by-products at the end of 20 days interfered so seriously with the determination of the end point that it was practically impossible to ascertain the reaction at this time.

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below, and is two-thirds blued after ten days. Following this, the litmus is reduced and the whole tube assumes a gray color in fifteen days. At the end of twenty days the peptonization is complete and the fluid is dark blue to dark blue green in color. Coagulation begins on the fifth day, followed by clearing, which is complete in twenty days.

20° C.—Milk begins to turn blue from the surface downward after seven days, becoming lighter below, and is completely blued after fourteen days. Following this the fluid becomes gray with a blue ring at the surface, and at the end of 35 days it is between dark blue gray and dark green gray, *i. e.* green gray No. 2 and A-blue green dark, in color. Coagulation begins the seventh day, followed by peptonization, which is complete in 35 days.

10. GELATIN COLONIES.—*Growth*—moderately rapid at 20° C. *Form*—round. *Elevation*—crateriform, liquefying. *Edge*—entire. *Liquefaction*—saucer. *Size*—4 mm. diameter in three days.

11. AGAR COLONIES.—*Growth*—moderately rapid at 20° C. *Form*—round. (Plate I, Figs. 3, 4.) *Elevation*—slightly convex. *Edge*—undulate. *Internal structure*—gyrose, marked by wavy lines indefinitely placed. (Fig. III.) *Size of majority*—2 mm. in five days. Deep colonies lens-shaped. (Plate I, Fig. 5.)

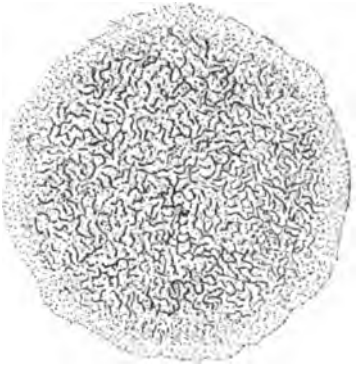

FIG. III

12. STARCH JELLY.—Prepared from Uschinsky's solution and potato starch. *Growth*—moderate. *Medium*—stained yellowish green. *Diastatic action*—absent.

13. COHN'S SOLUTION.—No growth.

14. USCHINSKY'S SOLUTION.—No growth.

15. FERMI'S SOLUTION.—Growth abundant, heavy clouding, white wrinkled pellicle at surface in ten days and small amount of sediment.

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16. NAEGLI'S SOLUTION.—Slight transient clouding.

17. FRAENKEL'S SOLUTION.—Heavy clouding and surface scum in ten days.

18. DUNHAM'S SOLUTION.—Uniform, heavy clouding and considerable white compact sediment, somewhat viscid on agitation.

19. ASPARAGIN SOLUTION.—Growth, abundant. Fluid, colored light green.

20. SOHNGEN'S SOLUTION.—(Urea.) No growth.

21. SODIUM CHLORIDE IN BOUILLON.—Nutrient broth containing 1% peptone, but without salt, was used in this determination. To measured quantities of this medium, different amounts of chemically pure sodium chloride were added, giving a range in the salt content from 0.0% to 5.0%. Four tubes of each concentration were prepared, and each set differed from the others by 0.25%. One loop of a 24-hour broth culture was used for the inoculation, and the tubes were kept at 28° C.

Growth occurred in 24 hours in all concentrations up to 2.0%. No difference could be observed in the amount of growth from 0.0% to 0.75%, however, with 1.0% and 1.25% there was less, and with 1.5% and 1.75% there was still less. After 48 hours, growth appeared in the tubes containing 2.0% to 2.75%; after three days in 3.0% and 3.25%; after eight days one of the set with 3.5% became turbid. Beyond this point no growth took place, 3.75% being sufficient to prevent growth.

The detailed results of this experiment are given in Table I.

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TABLE I

The Effect of Sodium Chloride upon Growth in Bouillon

%NaCl	Days Before Growth Appeared														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
.50	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
.75	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1.00	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1.25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1.50	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1.75	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2.00	−	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2.25	−	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2.50	−	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2.75	−	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3.00	−	−	+	+	+	+	+	+	+	+	+	+	+	+	+
3.25	−	−	+	+	+	+	+	+	+	+	+	+	+	+	+
3.50	−	−	−	−	−	−	−	+	+	+	+	+	+	+	+
3.75	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
4.00	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
4.25	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
4.50	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
4.75	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
5.00	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

22. GROWTH IN BOUILLON OVER CHLOROFORM.—To 10 c.c. of nutrient broth in test tubes, 5 c.c. of chloroform were added with aseptic precautions. Duplicate tubes thus prepared were inoculated with one loop of a 24-hour broth culture and held at 20° C. No growth took place in the tubes containing the chloroform after 60 days, while a check tube of plain broth gave abundant growth in 24 hours.

23. NITROGEN.—Peptone, asparagin, urea and ammonium tartrate have been used in different media as a source of nitrogen for the organism. Nitrogen was obtained very readily, as would be expected, from the first of these, as it occurred in nutrient broth, nutrient gelatin, nutrient agar and Dunham's solution. Good growth was also secured from the nitrogen of the asparagin present in Jordan's asparagin solution.

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Jordan's Asparagin Solution

Redistilled water	1000 c.c.
Asparagin	2 grams
$MgSO_4$	1 gram
K_2HPO_4	1 gram

No growth was obtained from either the urea nitrogen in Sohngen's solution, or the ammonia nitrogen in the ammonium tartrate of Cohn's solution.

Sohngen's Solution

Tap water	500. c.c.
Urea	25. grams
K_2HPO_4	.25 gram
Calcium malate	2.50 grams

24. BEST MEDIA FOR LONG-CONTINUED GROWTH.—Standard nutrient agar +10.

25. QUICK TESTS FOR DIFFERENTIAL PURPOSES.—Liquefaction of gelatin; coagulation and peptonization of plain milk; growth in Fermi's solution, absence of growth in Uschinsky's and Cohn's solutions; production of acid from dextrose, galactose and saccharose in sugar free broth; yellowish-green color produced in starch jelly.

III. PHYSICAL AND BIOCHEMICAL FEATURES

1. GAS PRODUCTION.—The power of the organism to produce gas from dextrose, galactose, saccharose, mannite, laevulose, maltose, inulin, lactose and glycerine was determined by adding 1% of the different fermentable substances to +10 sugar free bouillon. Two fermentation tubes of each were prepared, and after sterilization, they were inoculated with a 72-hour agar culture and placed in an incubator at 28° C. *No gas was formed in any case.* No growth occurred in the closed arm, and there was a sharp line of demarcation between the growth in the upper part of the U and the closed arm. After fourteen days the reaction of the different inoculated broths was tested with litmus, and it was found to be acid in the case of glucose, galactose and saccharose, and alkaline in the remainder.

2. AMMONIA PRODUCTION.—Nutrient bouillon containing 1% peptone and Jordan's asparagin solution with 0.2% asparagin were used in determining the power of the organism to produce ammonia. Duplicate 100 c.c. portions of each solution in 250 c.c. Erlenmeyer flasks were inoculated with two loops of a 24-hour broth culture and kept at 20° C. Uninoculated controls of each solution were carried along with these at the same time. After five days, both cultures and controls were analyzed for ammonia by distillation with mag-

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nesia. The asparagin solution yielded considerably more ammonia than the nutrient bouillon. The results follow:

TABLE II
Ammonia Production

Nutrient solution	Milligrams N as NH_3 in 100 c.c. culture after 5 days	Milligrams N as NH_3 in 100 c.c. sterile culture solution	Milligrams N as NH_3 produced by the micro-organisms
Nutrient bouillon...	15.1308 15.2709	9.03645	6.09435 6.23445
Asparagin solution..	27.4596 29.0707	0.9807	26.47890 28.09000

3. NITRATES IN NITRATE BROTH.—Nitrates are not reduced after five days either at 20° C. or 28° C.

4. INDOL PRODUCTION.—Neither indol nor the cholera red reaction is produced in Dunham's peptone solution after 10 days at 20° C.

5. ACID PRODUCTION FROM SUGARS AND GLYCERINE.—One hundred c.c. portions of +10 sugar free broth to which 1% of the different fermentable substances was added were inoculated with two loops of 24-hour broth culture and kept at 20° C. Five c.c. were taken from each flask with a sterile pipette daily and the reaction to phenolphthalein determined with n/10 NaOH or n/10 HCl. The titrations were made by adding the 5 c.c. of the sample to 45 c.c. of hot, freshly boiled distilled water, rather than by boiling the sample with the water. This was done in order to avoid the loss of any volatile acid that might be present. At the end of ten days there was a slight increase in the acidity of the broths containing saccharose, galactose and dextrose, from +10 to +13, altho in all probability this does not begin to represent the actual amount of acid produced, since considerable quantities must have been neutralized by the ammonia which we know is formed. The remaining broths were more alkaline at the end of the ten days than at the beginning. The detailed titrations are given in Table III.

TABLE III
Production of Acid from Sugars and Glycerine

250 c.c. Erlenmeyer flasks containing 100 c.c. sugar-free broth and 1 percent	Reaction in degrees Fuller's scale after given number of days										
	0	1	2	3	4	5	6	7	8	9	10
Check	10	10	9	7	6	5	5	5	4	1	—2
Dextrose	10	10	10	10	9	9	9	9	11	13	13
Galactose	10	10	10	9	9	10	11	11	12	13	13
Saccharose	10	10	10	8	8	9	9	11	12	12	13
Mannite	10	8	8	8	6	5	4	4	4	2	—5
Laevulose	10	8	8	8	6	6	5	4	4	4	0
Maltose	10	8	8	6	6	5	5	5	3	—2	—2
Inulin	10	8	6	6	6	6	5	5	3	3	—3
Lactose	10	10	10	7	6	6	5	5	5	1	—4
Glycerine	10	8	8	8	5	5	4	4	4	4	4

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6. HYDROGEN SULPHIDE PRODUCTION.—No hydrogen sulphide is produced. This was determined by means of both iron gelatin and nutrient broth.

In the former case, stab cultures were made in +10 nutrient gelatin which contained 0.5% of iron potassium tartrate. No blackening took place along the line of the stab as the result of the formation of iron sulphide.

In the second method of determination, tubes of nutrient broth were inoculated and held at 28° C. After 24 hours, strips of filter paper, moistened with lead acetate were suspended in the tubes above the fluid; these were remoistened each day for five days, but after fifteen days no blackening of the paper had taken place, due to the formation of lead sulphide.

7. TOLERATION OF ACIDS.—The toleration of acids is slight. We have determined this point with relation to citric, malic, oxalic and tartaric acids by adding different amounts of these to neutral nutrient bouillon in quantity sufficient to give the broth the acidities +15, +30 and +45. Three tubes of each acidity were prepared from each acid. They were inoculated with one loop of a 24-hour broth culture and subsequently kept at 28° C. In 24 hours, the +15 tubes of all the acids were uniformly turbid, but none of the others gave any growth. After twenty days the results remained unchanged.

Hydrochloric acid added to nutrient broth sufficient to give it a reaction of +27 inhibits growth.

8. TOLERATION OF ALKALIES.—So far as our studies go, the toleration of alkalies is even less than that of acids, altho this point has been determined for only one alkali, NaOH. Sodium hydroxide added to nutrient broth sufficient to give it a reaction —11 inhibits growth.

9. OPTIMUM REACTION.—The optimum reaction for growth in nutrient broth appears to be about +8. This was determined by adding to 20 c.c. portions of sterile broth, with aseptic precautions, sufficient normal NaOH or HCl as the case required, to give a series of broths ranging from +41° to —17° and differing from each other by 2 degrees. The contents of each flask were distributed into four sterile tubes by means of sterile pipettes, and without further sterilization, three of each set were inoculated with one loop of a 24-hour broth culture. The fourth tube of each set was kept uninoculated as a check against possible contamination, but in no case did any of these develop growth. The inoculated tubes were kept at 28° C.

After 24 hours, growth was present from +21 to —5, in 48 hours, it appeared in —7, and in 72 hours in +23, in 7 days in —9.

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and in 12 days in +25. Beyond these points no growth took place, from which we may conclude that the limits of growth are from —9 on the alkaline side to +25 on the acid.

After 72 hours there was a marked difference in the degree of turbidity in the different tubes. From +5 to +11 the growth was best; from +13 to +19 there was a gradual decrease, and beyond +19 there was an abrupt falling off. Going in the other direction, there was a heavy growth in +3, but not as good as in +5; in +1 the turbidity was not as decided as in +3, and beyond this there was an abrupt drop.

From this, it appears that conditons for growth became very restricted beyond +19 on the one side and beyond +1 on the other, and altho growth was not entirely inhibited until +27 was reached in the one direction and —11 in the other, the optimum reaction seems to lie between +5 and +11, probably about +8.

10. VITALITY ON CULTURE MEDIA.—Long. By transplanting the culture once every two weeks on nutrient agar, no difficulty has been experienced in keeping it alive and active for ten months.

11. TEMPERATURE RELATIONS.—The thermal death point lies between 49° C. and 50° C. Ten c.c. portions of nutrient broth in thin-walled test tubes of uniform diameter (16 mm.) were inoculated with one loop of a 24-hour broth culture, and after allowing three to five minutes for thoro diffusion, four tubes for each temperature considered were plunged into water of the desired temperature up to the plugs. They were left there for exactly ten minutes and then immediately cooled in cold water. The water in the bath where the determinations were made was kept in constant motion, thus insuring a uniform temperature, by a horizontal paddle operated by a water motor. The effect upon growth was determined for each degree of temperature from 45° C. to 55° C. Good growth took place in all tubes heated up to and including 49° C., but none occurred beyond that.

Optimum temperature.—The best growth was obtained between 27° and 28° C. No growth takes place at 37½° C.; good growth occurs at 20°, but it is not as abundant as at 28°. At 7° C., sufficient growth results in 48 hours to define the line of inoculation on an agar streak, while in two weeks the growth is about the same as a 24-hour culture at 20° C., *i. e.* moderate.

12. EFFECT OF DRYING.—The organism is rather resistant to drying. Flamed cover-glasses were spread thinly with a suspension of a 24-hour agar culture in distilled water and allowed to dry in the air. They were afterwards placed in sterile, covered petri-dishes, and every 24 hours for a period of 22 days, two of

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these were transferred to tubes of nutrient broth. There was considerable irregularity in the way these grew after different periods of drying, due presumably to the unevenness of the suspension. Up to 13 days drying, growth was fairly uniform, but none occurred again until the 18th day and then not until 21 days. No growth took place with the films dried for 22 days, but as none was dried longer than this, we can only say that 21 days dessication, under experimental conditions, was not sufficient to kill the organism.

13. PERCENT KILLED BY FREEZING.—(Salt and crushed ice.) The organism is relatively sensitive to freezing. From a 100 c.c. bouillon culture, 24 hours old, 10 c.c. were placed in each of four tubes of uniform diameter. These were packed in crushed ice and salt, frozen solid and kept frozen for 15, 30, 45, and 60 minutes respectively.

As soon as the specified time was up, each tube was thawed at once by placing it in cool water (four to five minutes required) and when entirely liquefied, dilution plates were made in +10 nutrient agar. Before freezing, dilution plates were made from the original culture as a check. Plates were kept at 20° C. and colonies counted after four days.

The original culture contained 19,800,000 bacteria per c.c. Eighty-five and 85/100 percent (8.85%) were killed by 15 minutes freezing; 93.03% by 30 minutes; 95.75% by 45 minutes, and 95.73% by 60 minutes. The number present after freezing 45 and 60 minutes is practically the same, altho the figures are slightly larger for the 60-minute tube; this is probably nothing more than an error due to dilution. The detailed results are given in Table IV.

TABLE IV
Sensitiveness to Freezing

Length of exposure to freezing temperature	Dilution	No. bacteria per c.c. after freezing	No. bacteria killed per c.c.	Percent killed
Check not frozen.	1-100,000	19,800,000	0	0
15 minutes	1-100,000	2,800,000	17,000,000	85.859
30 minutes	1-10,000	1,380,000	18,420,000	93.03
45 minutes	1-10,000	840,000	18,960,000	95.758
60 minutes	1-10,000	845,000	18,955,000	95.732

14. SUNLIGHT.—The organism is rather sensitive to the germicidal action of sunshine.

Flamed cover-glasses were spread thinly with a suspension of a 24-hour agar culture in distilled water and dried in the air. They were then exposed, germ side up, in covered petri-dishes to the bright sunshine. At the end of 15, 30, 45 minutes, 1, 1.5, 2,

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2.5 and 3 hours, respectively, two cover-glasses were removed and dropped into tubes of sterile broth which were then inoculated at 28° C. Growth resulted from all exposures up to and including 2 hours, but none took place with the 2.5 and 3-hour slips. The experiments were made at Fort Collins, Colo., January 21, 1916, beginning at 10:55, a. m. and ending at 1.55, p. m.

Thinly sown agar plates, with one-half of the bottom covered with black paper were exposed to bright sunshine, bottom up, on a bed of crushed ice for 15 minutes. Exposure made February 24, 1916, 2:05 to 2:20, p. m. After exposure, the plates were held at 20° C. for four days and the colonies that developed counted. An average count of five plates showed that 33.2% of the organisms were killed by an exposure of fifteen minutes under the conditions of the experiment. The detailed results are given in Table V.

TABLE V
Effect of Sunlight

No. colonies on exposed half of petri-dish	No. colonies on covered half of petri-dish	Gain of covered over exposed	Percent killed by sunlight
21	30	9	30
22	38	16	42
28	46	18	39
24	32	8	25
25	36	11	30

15. RELATION TO OXYGEN.—The organism is an obligative aerobe. Duplicate inoculations upon agar slants and thickly sown agar plates were placed in Novy jars, and a stream of hydrogen was allowed to flow thru them for two hours, after which they were sealed. After fifteen days no growth had taken place on either slants or plates. When returned to the air, abundant growth followed on both, after 48 hours, showing that the organisms had not been killed, but merely prevented from developing because of lack of air.

Parallel stroke inoculations on agar plates were covered at intervals with flamed cover-glasses so as to exclude all air. No growth whatever occurred beneath the glasses, while abundant growth took place where the air was not excluded.

Further evidence of the aerobic nature of the organism is to be had in its failure to develop in the closed arm of the fermentation tubes.

16. FERMENTS.—A proteolytic enzyme, probably pepsin, and lab ferment are produced. Neither diastase nor invertase is formed.

17. CRYSTALS.—No crystals have been observed.

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18. EFFECT OF GERMICIDES.—This has been reserved for a future publication.

IV. PATHOGENICITY

Pathogenic to field peas (*Pisum sativum* var. *arvense*) and garden peas (*Pisum sativum*). Not pathogenic to alfalfa (*Medicago sativa*), sweet clover—yellow—(*Melilotus officinalis*), crimson clover (*Trifolium incaratum*), mammoth clover (*Trifolium pratense*, var. *perenne*), cow peas (*Vigna unguiculata*), and garden beans (*Phaseolus vulgaris*).

V. GROUP NUMBER

Ps. 211.2322033

FIELD EXPERIMENTS

In conjunction with Mr. E. H. Thomas, of Alamosa, we have endeavored to study the progress of the disease in the field under natural conditions. To this end, Mr. Thomas staked and marked 25 field pea plants, most of which were affected, on June 12, 1915, on the ranch of Mr. W. F. Ulray between Monte Vista and Center.

These were observed at frequent intervals during the early summer, and changes in their condition from time to time were recorded as given in Table VI. The disease was most active from June 12 to June 17; on June 24 it had made but little further progress, and by July 1 it had practically disappeared.

Briefly, our study of these plants has brought out three points: First, badly affected shoots, where the infection is within a few nodes of the growing tip, are almost invariably killed outright; second, as a rule, when the original shoots are killed, new ones come up to replace them, except in very young plants; third, if the infection is confined to a few internodes next to the ground, the shoot outlives the disease and its growth is undisturbed.

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TABLE VI

Observations on 25 Field Pea Plants on the Ranch of W. F. Ulray, Center, Colorado, June 12 to June 24, 1915*

Plant No.	Date of Observation: June 12, 1915	June 17, 1915.	June 24, 1915.
1.	West shoot badly infected; east shoot diseased at base.	West shoot diseased all the way to terminal tendril; still growing. East shoot diseased to second branch; growth** ½ inch.	West plant ceased growing and throwing up new shoots 3 inches high. East plant, growth 2 in.
2.	Shoot to east—first 6 internodes badly diseased; trace on 8th and 10th; another shoot of same plant affected just on 1st internode; another shows trace.	East shoot dead; 2nd shoot diseased over 1st 7 internodes and traces on 8th and 9th; 3d, just at base; 2nd and 3d growing.	New branches starting which have made 4-inch growth — old unchanged shoots.
3.	Slight infection at base.	Looks thrifty but infection solid over 5 internodes and on branch at 8th node; ¾ in. growth.	No advance in disease; whole vine growing—3 in.
4.	Slight infection at base of one shoot and others normal.	Infected shoot shows disease over 6 internodes, ½ in. growth; normal shoot 3 in. growth; 1 dead shoot and 2 others affected over 4 internodes.	Four-inch growth on all shoots.
5.	East vine infected on 4 internodes; west not; just starting to branch.	East vine infected over 6 internodes, growth 1¼ in.; 2 new branches have developed; west shoot normal.	East plant blooming—growth 2 in.; normal.
6.	One shoot infected on first 3 internodes.	Diseased on first 6 internodes; growth 4 in.	No growth, altho infection is not spreading.

*Observations of June 12 and 24 made by Mr. Thomas.
**The growth recorded refers to growth since last observation.

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TABLE VI—Continued

Observations on 25 Field Pea Plants on the Ranch of W. F. Ulray, Center, Colorado, June 12 to June 24, 1915

Plant No.	Date of Observation: June 12, 1915.	June 17, 1915.	June 24, 1915.
7.	Normal, no disease.	Stem and leaves both diseased on first 5 internodes. Many separate leaf infections; growth, 1—¾ in.	Practically no changes.
8.	Not diseased, but inoculated by pricking into stem with knife infected from diseased plant. Second shoot pricked with knife before contamination.	Stem shows decided watery yellowish patches where inoculated. Check plant normal; growth 2 in.	Inoculated plant shows disease over 6 internodes; growth 2 in. Four new shoots coming up. Check plant normal; growth 4 in.
9.	Slightly infected, no marked discoloration.	Seven internodes involved, watery new shoots starting; ½ in. growth.	Disease has not spread; growth 6 in., new shoots appeared, 1 in. long.
10.	Two shoots normal.	One shoot very badly involved, other normal, with 2½ inch growth.	Diseased shoot practically dead; other branch normal; 2½ in. growth.
11.	Entire clump of shoots infected.	All shoots sickly; ¼ in. growth.	Disease checked; growth 5 in.
12.	Normal.	Normal; growth 2 in.	Normal; growth 2 in.
13.	Badly infected up to 5th internode, inclusive.	Infected over 7 internodes; growth ¾ in. New shoots developing.	No growth; 1 new shoot dead and 3 others just starting.

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TABLE VI—Continued

Observations on 25 Field Pea Plants on the Ranch of W. F. Ulray, Center, Colorado, June 12 to June 24, 1915

Plant No.	Date of Observation:		
	June 12, 1915.	June 17, 1915.	June 24, 1915.
14.	In reality 2 plants, red and white stem; disease just showing.	Red vine—3 shoots: 1 dead, 1 healthy, 1 infected on 6th internode; no growth. White vine, traces just showing on petiole of bottom leaf; 1 in. growth.	Red vine—2 shoots growing, 2½ in. White plant — no spread of disease; 4-in. growth.
15.	Three shoots, slight traces.	One shoot dead, 2nd small, badly infected, 3d with traces on 3d and 4th internode; branch at 4th node diseased; growth 3 in.	Second, dead; 3d, has grown 6 in., disease on 4th internode inactive.
16.	Normal.	Slight leaf infection on leaves at base; growth, 2½ in.	Disease has not spread; growth 2 in.
17.	Two diseased plants.	South plant diseased and watery to 9th node, new shoot starting, no growth. North plant, 4 branches: 1 dead, 1 badly affected, 2 normal; no growth. Red stem.	Original plants dead; 1 new shoot 8 in.
18.	Clump of small yellow shoots; badly diseased; nearly gone.	Practically dead; new shoots coming.	Original plants dead, 1 new shoot 8 in.
19.	West plant diseased; east normal.	West plant, petiole at 4th node affected, growth 1 in. East plant, slight infection on 1 branch, 3 healthy shoots; growth 2 in.	Disease has spread to entire plants, growth ½ in.

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TABLE VI—Continued

Observations on 25 Field Pea Plants on the Ranch of W. F. Ulray, Center, Colorado, June 12 to June 24, 1915

Plant No.	Date of Observation:		
	June 12, 1915.	June 17, 1915.	June 24, 1915.
20.	Just showing disease below first branch.	One entire shoot dead and 1 healthy; growth 2 in.	No growth on old shoots; new shoots growing rapidly, 6 in.
21.	Slight infection at base.	One shoot frosted, 1 shows trace of disease at 2nd internode, and 1 infected at growing tip. Second shoot has grown 2 in.	Growth 1½ in. Plants same.
22.	White vine diseased at base; red vine normal.	Disease up to 3d node on white vine, and side branch involved. Red vine normal.	Disease to 5th node on white vine, growth 6 in. Red vine growing, 6 in.
23.	Disease beginning to show on lower leaves.	Three shoots: 1 dead, 1 diseased to 5th node, and 1 healthy.	Diseased branch has grown 1 in.; healthy shoot, 4 in.
24.	Normal.	Leaf infections common and 1 shoot affected to the 8th node. Normal stem has grown 2-¾ in.	Little change, practically no growth on infected stems.
25.	Normal.	Three shoots: 1 dead, 1 diseased, over 4 internodes, and 1 normal.	Diseased shoot has grown 4 inches; normal, 6 in.

Observations, July 1, 1915

Mr. Thomas visited this field on July 1 and found all remaining plants making good growth. The vines were badly matted around the stakes so that it was impossible to identify the particular shoots observed before. There was some evidence of whole plants having been killed, but in the majority of cases, new shoots replaced badly infected ones while stems with the disease on lower leaves and internodes either branched below the infection, or, in many cases, continued to grow in advance of the disease.

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In connection with extensive variety tests which Mr. Thomas was conducting on field peas for forage purposes at La Jara, we have had an excellent opportunity to observe disease resistance to the bacterial blight. Out of the 48 varieties which we examined, there were 8 desirable varieties from a forage standpoint that showed any appreciable degree of resistance. Almost without exception, the best forage peas were the worst affected by the disease. The results of our observations on disease resistance are given in Table VII. The peas were planted May 3, 1915, and observed June 17, 1915.

Brief descriptions of the forage qualities of the different peas follow:

OBSERVATIONS MADE AT LA JARA, COLORADO, AT TIME OF HARVEST, BY E. H. THOMAS, COUNTY AGENT

All varieties planted under same conditions and at same time; four fifty-foot rows of each. Planted May 3, 1915. Seed furnished by Bureau of Forage Crop Investigations and by experiment stations of Idaho, Washington, Oregon, Minnesota and Ontario. Some varieties were also furnished by the W. A. Davis Seed Company, and the Allen Seed Company. Some seed was purchased from points in the north and west.

NO. 11087.—EUGENE.—Produced slender short vine at La Jara. Yield of forage fairly heavy, with many well-filled pods. Should be excellent pea seed for heavy land, fairly early maturing.

NO. 16130.—GOLDEN VINE.—Produced a tall, medium-sized vine; fairly good quantity of forage, but with few pods and they were poorly matured. Might make good if planted early in light soil.

NO. 16436.—GREY WINTER.—Produced medium length, small-sized vine. Produced good quantity forage. Was extremely well podded but rather immature. Believe that peas should be sown probably on heavy or medium heavy soil late in fall or very early spring.

NO. 18455.—SHANGHAI.—Produced medium length, slender vine. Yielded fair amount of forage. Many medium-sized pods containing rather hard, medium-sized peas which shatter rather easily. Would no doubt make good forage or grazing pea on fairly strong land. Medium late.

NO. 19788.—POTTER.—Produced long coarse vine. Good amount forage. Yielded fair number pods, but poorly matured. Would probably make excellent forage pea on medium or heavy soil. Should be sown very early in spring.

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NO. 20467.—SOLO.—Grown on medium, heavy land, produced long, medium-sized vine, yielding very good quantity of forage. Vine is extremely well podded thruout entire length; peas are rather soft. This variety should be excellent forage pea on heavy land and seed on lighter soils.

NO. 21288.—BANGALIA.—Slender, short vine, produced rather moderate quantity of forage when grown on medium, heavy soil. Produced a great many small-sized pods; rather early, drouth-resisting, should be great seed producer on heavy soils (or medium). Land should be fairly clean.

NO. 21289.—DESI.—Great number small, well-filled pods on short vine. Yield of forage light. Should make great grain production on heavy or medium heavy soils. *Do not* shatter easily.

NO. 21290.—KABILYA.—Produces medium vine. Good amount forage. Many pods. Excellent forage pea for heavy land; probably good seed pea on lighter soils. Should be planted early in spring.

NO. 21709.—AMORITI.—Medium length small-sized vine; fair yield forage. Many pods. Should be good pea for all classes of land. Seed and forage for heavy soils, also for medium heavy, and seed for light soils. Matures in good season, but should be planted rather early.

NO. 22007.—ALEXANDER.—Only medium yield of vine and seed. Does not seem to be anything extraordinary. Not enough pods for heavy land, nor enough vine for light land. Only fairly good yielder.

NO. 22036.—AGNES.—Long, coarse vine; fairly heavy amount of forage, but does not produce many pods, and is very late, should be planted very early in spring. Might make good forage pea for light land.

NO. 22037.—ARCHER.—Has long, coarse vine, good yield of forage, fair number of pods. More seed than 22036, but nothing extra; might make good forage pea on lighter soils.

NO. 22041.—GREGORY.—Same general type as 22037, but with fewer pods. Rank vine. Might make good forage pea for light soils. Should be planted very *early*.

NO. 22044.—PARAGON 12. Long, medium-sized stem; heavy yield of forage; medium number of pods. Might be good pea on lighter soils. Should be planted *very* early.

NO. 22078.—KILLARNEY.—Rather long, coarse stem, producing good quantity of forage. This variety is extremely well podded, compares rather favorably with 22043—Nelson. Should

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be sown on light land for grain and early on medium or heavy land for either seed or forage. Might make good forage on light land.

NO. 22638.—CLAMART.—Vine tall or long and coarse; yields great quantity of forage. Produces very few pods. Would probably be good pea for lighter grades of soil. Should be planted early, so as to insure maturing of pods.

NO. 22639.—WHITE SCIMITAR.—Vines of medium length; slender stems. Yielding fair amount of forage. An excellent producer, a great many pods from 1½ to 2 inches in length. Should be planted quite early, as this variety needs all the time possible to mature. A very good pea; would probably give best results from medium light land.

NO. 23290.—CHANG.—Medium length vine, coarse stem, yields good quantity forage. Many pods on upper or top half of vines, lower portion not so well podded. Would probably do better, pod more evenly if grown on light, sandy soil.

NO. 23848.—Vine long and fairly coarse. Fairly heavy yield of forage. Only moderate number of pods, but fair forage specimen; should be sown early.

NO. 23850.—LIMA.—Vines grow long and moderately coarse. Yields good amount of forage. Good many pods; very good pea, but should be planted early on light or medium light soils to secure best results for seed.

NO. 24314.—FRAILE.—Medium vine and stem; yields good quantity forage. Fairly well podded. Should be planted early to mature in good shape. Does not yield a great amount of either vine or grain.

NO. 25439.—OPENSHAW.—Vine of medium length, stem coarse. Good yield of forage. Great many pods. A good pea for almost any kind of land; forage and seed on heavy land, and seed on lighter grades. Plant fairly early.

NO. 25680.—BROWN ABYSSINIAN.—Medium vine and stem; fair yield of forage. Good yielder; many pods. *Does not* shatter easily. Should be good pea for harvesting; would grow in all grades of soil; earlier than all but a few varieties.

NO. 29368.—BLUE PRUSSIAN.—Vines medium, stems medium, yield of forage fair. Great many pods; would probably do well in clean, medium heavy land.

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NO. 29371.—CHURCH.—Vines tall; medium stems; very good yield of forage. Many pods, very good pea. Would probably seed heavily on light soils. Should be planted rather early.

WHITE MARROWFAT.—Stems coarse, vines of medium length, yield of forage good. Great many good-sized pods. Should be planted early to insure maturing.

CHANCELLOR.—Medium vine and stem; good yield of forage: many well developed pods on vines. Good pea for heavier soils as well as excellent for seed on light soils.

TOM LEXINGTON.—Not much vine; yield of forage only fairly good. Quite a number of good-sized pods. A beautiful pea. Should be sown on good grade of clean ground.

MCKAY.—Very rank vine, yields much forage, very few pods. Would probably do better if planted early on higher lighter soil.

PROLIFIC.—Vines short; stem medium. Yield of forage rather light. A great many well-developed pods; peas are rather hard, might be grazed, as they shatter rather easily; would probably grow best on medium soil, but ought to be good peas on any clean ground.

ADVANCER.—Short slender vine, yield of forage rather light. Many fairly well-developed pods. Might do well on high medium heavy ground.

CARLTON.—Vines long and stem medium; fair yield of forage. Vine fairly well podded on upper position, lower 24 inches decayed at time of harvest. Might plant rather thin on higher land. Plant early.

ARTHUR SELDEN.—Vine very coarse and short. Good yield of forage. Good number fair-sized pods. Should be planted very early (when compared with early varieties).

PICKTON.—Vine rank and coarse, heavy yield forage. Good many fair-sized pods. Should plant early on light or medium soils.

EARLY FORAGE.—Short, sturdy vine. Pods mature even earlier than Horsford, and is heavier podded. Peas are soft, wrinkled and sweet; ought to be excellent for early grazing, yield of forage good, considering size of vine. Believe that this variety should be sown rather thick; should do well on heavy land.

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TABLE VII

Disease Resistance—Variety Tests at La Jara, Colorado, Conducted by Mr. E. H. Thomas. Season 1915—Observations made June 17, 1915

Variety No.	Variety Name.	Prevalence of Disease.	Quality as Forage Pea.
11097	Eugene	Bad	Good
16130	Golden Vine	Very bad	Very good
16436	Gray Winter	Bad	Poor
18455*	Shanghai	Slight	Good
19788	Potter	Bad	Poor
20467*	Solo	Slight	Good
21288	Bangalia	Bad	Very good
21289	Desi	Moderate	Poor
21290*	Kabilya	Very slight	Good
21709	Amoriti	Bad	Good
22007	Alexander	Very slight	Poor
22036	Agnes	Bad	Fair
22037	Archer	Moderate	Poor
22041	Gregory	Considerable	Poor
22044	Paragon 12	Moderate	Good but late
22078*	Killarney	Slight	Very good
22638	Clamart	Very bad	Poor
22639	White Scimitar	Very bad	Poor
23290*	Chang	Slight	Very good
23848	.....	Very bad	Good
23850	Lima	Slight	Fair
24314	Fraile	Very bad	Poor
25439	Openshaw	Very bad	Very good
25680	Br. Abyssinian	Slight	Fair
29368	Blue Prussian	Bad	Good
29371	Church	Bad	Good
	White Marrowfat	Considerable	Fair
	Chancellor	Moderate	Fair
	Tom Lexington	Very bad	Very good
	McKay	Bad	Good
	Prolific	Bad	Good
	Advancer	Very bad	Good
	Carlton	Bad	Poor
	Arthur Selden	Very bad	Very good
	Pickton	Bad	Fair
	Early Forage	Very bad	Very good
	Braden	Moderate	Good
	White Mexican	Very bad	Good
	Paragon	Very bad	Good, but late
	Late Forage	Bad	Very good
	Minn. 62	Bad	Good
26819	.....	Very bad	Very good
31073*	.....	Slight	Good
32003	.....	Very slight	Fair
32061	.....	Slight	Fair
32065*	.....	Very slight	Good
32104*	.....	Slight	Good
32123	.....	Very slight	Fair

*The promising varieties are marked with an asterisk (*).

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METHOD OF INFECTION

Both our laboratory experiments and our field observations indicate that the causal organism enters the plants either thru the stomata or thru wounds produced by mechanical injuries.

In looking into the history of the trouble last spring we found one striking case where the outbreak unquestionably followed cultivation with a spike-toothed harrow at a time when the wind was carrying quantities of soil. The custom of harrowing to break the crust and to conserve moisture is a dangerous practice, because it wounds the tender plants and opens the way for soil infection. This was brought to our attention in a very graphic manner in a field where a large number of varieties had been planted for experimental purposes. A spike-toothed harrow had been dragged across the lower part of one of these rows and the upper end left untouched; all of the varieties blighted more or less in that portion of the row that was harrowed, while in the unharrowed part several of the same varieties exhibited marked resistance.

Two other instances were noted where infection followed closely upon a severe sand-storm which bruised the vines and literally injected the tissue with germ-laden soil particles. In fact, soil-laden wind alone, where it blows as violently and persistently as it does in Colorado in the springtime, is adequate explanation for all the infection that might ever occur in our State.

CONTROL MEASURES

1. Resistant varieties offer the only satisfactory remedy for the blight, and in the next two years we shall endeavor to obtain strains that are disease-resistant and, at the same time, desirable types both for forage and canning purposes.

2. In the meantime, when practicable, we would suggest planting from ten days to two weeks later than is the local custom.

3. So far as possible, avoid mechanical injury to the plants by harrowing or by other similar practices.

4. Avoid planting peas on the same land that was in peas the previous year, or where the disease has been present.

5. While we have had no opportunity as yet of determining whether the blight organism can pass thru the digestive tract of animals, fed with diseased vines, unharmed, and thus infect the manure, it may not be out of place to suggest the possibility of this at this time, and if we should have occasion to use any such manure on our gardens or in our fields, to remember that we may be sowing the seed of endless woe. Until we know definitely that

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such fertilizer is free from this objection, its use should be regarded as a doubtful practice.

SUMMARY

1. The bacterial stem blight of field and garden peas occurs generally over the San Luis Valley and Northern Colorado, and to a limited extent in Nebraska, South Dakota and Utah.

2. It is characterized by the watery, olive-green to olive-brown color of the stems, and by the yellowish, bruised and watery-appearing stipules and leaflets.

3. A severe outbreak when the plants are young may reduce the stand one-third.

4. The blight is caused by *Pseudomonas pisi,* n. sp., which enters the tissue thru the stomata and thru wounds produced by mechanical injury.

5. Resistant varieties offer the only satisfactory remedy for the trouble, altho later planting may reduce the amount of the injury somewhat.

ACKNOWLEDGMENT

I am very greatly indebted to Professor B. O. Longyear for the preparation of the colored plate which appears in this bulletin, and to Mr. E. H. Thomas, of Alamosa, Colorado, for the many courtesies extended to me while studying the disease in the San Luis Valley, and for much of the field data presented herewith.

EXPLANATION OF PLATES.

PLATE I.

FIG. 1.—Pea leaf sprayed with a suspension of *Ps. pisi,* showing stomatal infection six days after inoculation.

FIG. 2.—Gelatin stab culture of *Ps. pisi,* kept at 20° C. and photographed after three days. Broad funnel-shaped liquefaction at surface, and slight growth along the line of the stab.

FIG. 3.—Gelatin stab culture of *Ps. pisi,* kept at 20° C. and photographed after eight days. Stratiform liquefaction at the surface, and slight growth along the line of the stab.

PLATE II.

FIG. 1.—Photomicrograph of *Ps. pisi* stained with carbol fuchsin, 24-hour agar culture. ×1000.

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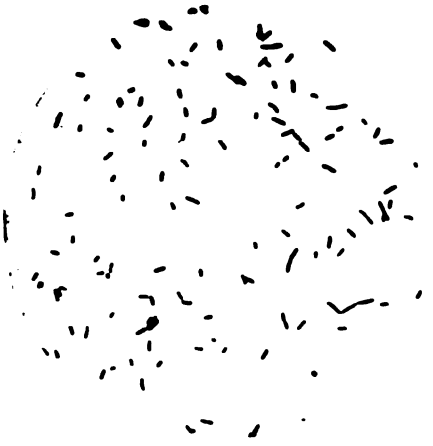
PLATE I



1.

2.

3.

4.

5.

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PLATE II

Fig. 1

Fig. 2

Fig. 3

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FIG. 2.—Chains of *Ps. pisi* from 24-hour agar culture. Stained with carbol fuchsin. ×1000.

FIG. 3.—Agar plate culture of *Ps. pisi*, showing surface and deep colonies. Five days old. Actual size.

FIG. 4.—Surface colony from agar plate. Five days old. ×100.

FIG. 5.—Deep colonies of *Ps. pisi* from agar plate. Five days old. ×100.

COLORED PLATE.

LEFT-HAND FIGURE.—Characteristic yellow, olive green, watery stipules and stem; recent infection.

MIDDLE FIGURE.—Diseased pea vine with olive green, watery stem and healthy shoot coming from below diseased portion. Infection active.

RIGHT-HAND FIGURE.—Pea vine in advanced stage of the disease.

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OF THE

Colorado Agricultural College

A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART III

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OCT 13 20

A STUDY OF COLORADO WHEAT

By W. P. HEADDEN

PART III

In the preceding portions of this work I have shown that the moisture which we determined at short intervals throughout the two seasons varied but little. These intervals were not all equal, but varied according to the weather or the application of water, irrigation. For the actual variation of this factor reference may be had to Bulletins 208 and 217. The moisture in the soil during the two seasons was not far from 15 percent. The plants did not, at any time, show the need of more water than was at their disposal.

The total nitrogen in the soil is given for a rather large number of samples of the surface soil, for the top four feet, and also for the top eleven feet. The surface portion varies considerably in the amount of total nitrogen present in it. The total nitrogen in 150 samples, taken at the same time and from a space 5 by 30 feet, varied from 0.11016 to 0.14552 percent. We have here a difference of 0.0354 per-cent of nitrogen. This variation involves an amount of nitrogen many times greater than that which, in the form of sodic nitrate, is necessary to produce most positive effects upon the growth and composition of the plant. The application of nitric nitrogen equivalent to 0.001 percent, or 10 parts per million is, in our case, sufficient to cause the grain to lodge, to change the physical properties of the kernels, also to increase the nitrogen in both the plant and kernel, and to affect the amounts of the various ash constituents appropriated.

THE FIXATION OF NITROGEN IN SOILS USED

In regard to the fixation of nitrogen by this soil, I have so far relied upon laboratory experiments, because the variation in the nitrogen content of field samples on a given date is greater than the amounts involved in the question of fixation itself. In the case just mentioned, we had a difference of 354 parts per million, and this difference was found on contiguous areas of 1 square foot each. The largest actual increase in the total nitrogen observed in this soil to which nothing but boiled distilled water had been added, was 105 parts per million; stated otherwise, samples gathered from the field on different dates cannot be relied on to either prove or disprove the fact

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of fixation, for if the samples taken for this purpose at different dates had been taken on the same date, they would probably have varied in the same direction to such an extent as to render any conclusions based on them unsatisfactory, if not useless. It is not feasible to increase the number of subsamples sufficiently, in cases where one samples the land every fortnight, to eliminate this uncertainty.

If it be objected that the fixation found in a laboratory experiment lasting from 25 to 30 days is not a safe basis for estimating the extent to which this process may take place in the soil, the answer is evident. The results of the laboratory experiments prove conclusively, especially where the experiment is made with the soil without addition of anything except water enough to produce a favorable degree of moisture, 18 to 20 percent, that the soil is populated by an efficient nitrogen-fixing flora. While a laboratory experiment extending over 25 or 30 days does not prove that the fixation will proceed at the same rate for every other period of 25 or 30 days throughout the year, it does show that fixation is going on and may reach 105 parts per million, or 420 pounds of nitrogen for the surface acre foot, in one or more 30-day periods during the year. If we assume that the fixation is constant at one-half this rate, 50 parts per million, it would account for a large amount of nitrogen, the quivalent of a little more than 7 tons of proteid substance *per annum*.

For the benefit of some reader not accustomed to think in these terms, it may be stated that a fifty-bushel crop of wheat will correspond to about 4,500 pounds of straw. If the wheat weighs 62 pounds per bushel and carries 2.0 per cent nitrogen while the straw carries 0.3 percent nitrogen (this is a higher percentage than we have found in the stems and leaves taken together), the total nitrogen removed by the crop will amount to 74.0 pounds for each acre. If we assume the whole of this nitrogen to have been removed from the surface foot of soil, it is only three-fourths of the maximum fixation and one and one-half times the minimum obtained for a period of 30 days. The laboratory experiments have shown that it is possible for this soil to obtain from the atmosphere as much nitrogen in 45 or 50 days as the assumed crop of 50 bushels per acre would remove. This process tends to keep up the supply of nitrogen, but it is almost certainly not uniform throughout the year. We cannot judge of the amount of fixation by the variation in the amount of nitrogen present, for there is a considerable wastage of nitrogen from our soils. That such wastage takes place is common knowledge, still we may illustrate it by the results of a single irrigation made in 1913 by which we moved about 300 pounds of nitrogen per acre beyond the reach of any ordinary, cultivated plant. This is only one cause of wastage. The writer does not know the results obtained by other observers, but his own results indicate a discrepancy of upwards of 300 pounds per acre for which he can give no satisfactory accounting.

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Realizing the weight of the misgivings that may be entertained regarding the applicability of laboratory results to this process of fixation, as it actually takes place in the field, which we have assumed in the preceding paragraphs, we have endeavored to meet them by taking 3,000 pounds of soil from the field, and determining the fixing power of this soil. The details of this experiment do not belong in this place but the general results are apropos to the question just raised.

The experiment was continued for 40 days under field conditions; the only departure from these that could possibly be urged against the experiment was that we endeavored to keep the moisture at uniformly 15.0 percent, it actually varied from this to 18.0 percent.

We found the maximum gain in total nitrogen during the fourth week of the experiment, when the average for the surface foot showed a gain of 45.5 p. p. m.

This period was followed by a rapid increase in the rate of nitrification. We have no check on the loss of nitric-nitrogen by its moving down to the bottom of our container and perhaps into the underlying soil. The important fact in this connection is that at the end of 40 days, this soil, to which nothing except ammonia-free distilled water had been added, showed a fixation of 36.0 p. p. m., calculated on the dry soil.

This experiment was performed under field conditions, not in an incubator nor in a laboratory, but with the soil taken from the wheat field and kept out of doors. It was protected so that animals could not have access to it, and so that no washings from neighboring soil in event of rain, could be carried down on it, and the immediately adjacent soil was wet down constantly to prevent blowing of foreign soil onto it.

We consider this conclusive proof that the laboratory results are applicable, and also that this soil fixes and nitrifies rapidly enough—we had an actual gain of 15.79 p. p. m. of nitric-nitrogen—to justify every claim made in this connection.

While I am persuaded that field samples can not be depended upon in the study of fixation, this is not the case with nitrification, for this nitrogen exists in a definite form which can be determined in its totality at any time with a very high degree of accuracy. That there is difficulty in obtaining representative samples does not need to be stated.

EFFECT OF WHEAT CROP ON FIXATION OF NITROGEN

We have followed the amounts of nitrates present in our soils for two years, and have shown that the amounts of nitrogen present in our soils in this form at different times vary greatly. After a thorough soaking of the land, or if the land is occupied by a good

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stand of plants, the nitric-nitrogen present is naturally small in quantity, but under other conditions, it is always higher, and often quite high, though we are not now speaking of exceptional cases. On 4 August, 1915, we found, in the top four feet of a fallow plot, 47.4 pounds of nitrogen in the form of nitrates and 7.2 pounds in a like depth of soil planted to wheat. These quantities of nitric-nitrogen are equivalent to 284.4 and 43.2 pounds of sodic nitrate respectively. If this were a single or an exceptional instance, it would show only that this difference might exist in the amounts of nitric-nitrogen present in cropped and fallow land. This, however, is not an exceptional instance, every series of samples taken, 66 in all, shows the same fact. It is not held that the crop has used up this amount of nitrogen, but it is held that the crop either hindered the formation of nitrates or did exhaust them to this extent. The crop certainly did use up nitrates present in the soil, and also possibly hindered the formation of them. If the latter be true it was only a hindrance and not a destruction of the power of the soil to nitrify, for we have shown that the nitrates are rapidly replaced in this soil as soon as the crop is removed. The same plot that on 4 August, 1915, showed the presence of nitric nitrogen, equivalent to 43.2 pounds of sodic nitrate, showed, on 13 December, 1915, taken to the same depth, the equivalent of 232.7 pounds, or five times as much as on 4 August. Nothing had been added to this soil except the wheat stubble which had been disced into the surface soil. Irrigation was not necessary, as enough rain had fallen to keep the soil fairly moist. It is not probable that the wheat stubble disced in modified, in any essential way, the process of nitrification, for the increase of nitrates in the soil began immediately after the removal of the crop and before the stubble was disced in. There is no question about the action of more considerable quantities of decaying organic matter upon the processes of fixation and nitrification but in this case the quantity did not seem to be sufficient to produce observable results, or obscure in any way the process of nitrification, for our samples were not taken close enough together to establish the rate of nitrification from one week to another or to detect variations in this rate.

The quantities of nitrogen thus transformed into nitrates during a single season are more than sufficient to justify their consideration in connection with our problem. We found in the 2nd, 3rd and 4th foot of a sample of this soil taken 29 April, 1913, 23.8, 33.8 and 12.9 parts nitric-nitrogen per million, respectively. These quantities seem high, but we have found in fallow spots in this same land, cultivated to beets, 22, 28, and 35 parts nitric-nitrogen per million in the surface portions of the soil. When one bears in mind that the ratio of available potassium in the land is so high that its specific action on the character of the wheat produced is easily recognized in the plumpness and color of the kernels, and that the supply of available phosphorus

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is such that the addition of considerable quantities of this element, up to 60 pounds of soluble phosphorus per acre, produces no perceptible effect upon the crop, it will be appreciated, that the formation of quantities of nitrates corresponding to the amounts of nitric-nitrogen given above, or even the less amounts indicated by our general samples, may produce a very pronounced influence upon the character and properties of the wheat produced.

In order to find out what effects we were to expect from the predominance of one or other of the three elements usually considered in this connection, nitrogen, phosphorus and potassium, but particularly of nitrogen, we applied these singly in different quantities, aiming to have a very excessive quantity in at least one case in each series of experiments. To these three elements of plant food we added water, because the supply of this is usually under our control in Colorado and our opportunity for studying its effects is better than that enjoyed by many other experimenters.

APPLICATION OF WATER A PHYSIOLOGICAL PROBLEM

I will digress to state what seems self evident, i.e., that the question of an advantageous or indispensable water supply to the wheat plant, for instance, is rather a physiological than an engineering question, though it is generally considered from the latter standpoint. It is not only a question of how much or little water is actually needed, but also a question of the time and manner of application. To be more specific, I believe that the application of one acre-foot of water at the proper time may produce just as favorable results as the same amount differently distributed in regard to time. Further, 1 foot, or even less, of water, applied at the proper time may produce just as good results as 2 or even 3 feet, provided that the supply at the proper time in the development of the plant be adequate to its needs; after this the water supplied is of little or no benefit, and produces but little or no effect upon the composition of the plant or grain. Two feet of water applied to the soil as irrigating water, even if it be distributed at intervals of a few days, eight to ten days, may do neither the plants nor the grain any harm, and produce no perceptible difference in the composition of either. Whereas, the same amount of water falling in a series of light rains would certainly prove detrimental, perhaps disastrous, even though the last ten, or possibly even fifteen days before harvest were fair and dry. A comparison of the composition of the plant, as indicated by the various forms of nitrogen and the ash constituents given for the crop of 1913, in Bulletin 208, with that for 1915 in Bulletin 217, in which years the plants received essentially the same amounts of water, will show how great a difference the manner of application may make. In 1913, the crop received 12 inches as irrigating water and 6.77 inches rainfall; in 1915, it received 13 inches of rainfall and 6 inches of irrigating water. The plants in 1915 contained less nitrogen and smaller

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amounts of ash-constituents. The variety of wheat referred to was the same and grown on the same land with the same fertilization. Further, it is a matter of common knowledge that a very light rainfall or heavy fog, just before the ripening period, may cause injury both to the quantity and quality of the crop. If this were not already so well known, we would appeal to our experience in 1914, when a comparatively small amount of rainfall injured our Defiance plots to an extreme extent and all of the plots seriously. In this case rust produced severe injury to the crop, but especially to the Defiance. There were some effects which could not be attributed directly to this parasite, especially in the light of other experiences, but probably should be attributed directly to the wetting of the plants.

EFFECTS OF NITROGEN, PHOSPHORUS AND POTASSIUM

To return to our subject, we found that under our conditions nitrogen produces the most marked effects upon the growth and composition of the plants; that phosphorus and potassium produced less effect than other observers have recorded. For instance, phosphorus did not hasten, nor the nitrate delay, maturation as observed by others. This statement holds irrespective of the amounts applied. It is true that rust interfered two years out of three, particularly in the case of the Defiance.

In the case of the Defiance, all amounts of nitrates applied caused lodging, and that badly. It produced the same tendency in the Red Fife and Kubanka, but these varieties did not suffer much on this account; they did, however, show other effects of the nitrates, such as heavier, darker leaves, slightly taller plants and longer heads, but the average number of kernels to the spikelet was found to be slightly lower. The kernels were smaller, darker in color, flinty, and sometimes shrunken.

Phosphorus, on our plots, produced no perceptible effect upon the growth of the plant, the time of ripening, or the physical properties of the kernels.

The plants on the plots which had received dressings of nitrate and were planted to Red Fife or Kubanka differed so little from the others, that it was only by the darker green color of the plants that one could readily distinguish them. This was not the case with the Defiance, for in these plots the wheat which had been dressed with nitrate went down flat, showing sharply the last drill row to which the nitrate was applied.

Potassium showed at one period a slight hastening in the development of the plant, but this advantage was soon lost and plants grown on the check plots and on those that had received an application of phosphorus, attained the same height and the same perfection of de-

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velopment, so that no difference in the plants grown on these plots could be perceived.

While there were but few, or almost no recognizable differences in the growth and ripening of the plants in comparison with the check plots, there were differences in the physical properties of the kernels. The kernels grown with the application of phosphorus, of potassium, and those on the check plots, were plump and of good size, while those grown with the application of nitrate, were smaller and somewhat shrunken. The chief physical characteristics were shown by the wheats grown with the addition of potassium and these were most pronounced in the Kubanka. These wheats show a difference in their general appearance, in the brightness of the kernel, and especially in the presence of mealy or half-mealy kernels. Yellow-berry was more prevalent than in wheats from the other plots, i.e., than in either those from the check plots or such as had been grown with the application of phosphorus. There are no decided differences between the physical appearances of wheats grown on check plots and those grown with the application of phosphorus. This is not the case with wheat grown with the addition of nitrogen; such wheats are, as has already been stated, small grained or even shrunken, dark colored, and flinty. The starchy or mealy berries are either greatly lessened in number or are absent.

So far, we have stated the physical differences shown by the plants and also the kernels. Bulletin 205 deals with the physical properties of the kernels, while Bulletins 208 and 217 deal with the soil, the chemical composition of the plants, and some other factors. There we find that these fertilizers exert specific influences which are not apparent in the physical appearance of the plants. The greatest correspondence between the physical appearance and chemical effects is found in the case of nitrogen, which produces in the plant an appearance of luxuriance. We find that it increases the nitrogen content of the plant, and modifies the amount and percentage composition of the ash. Further, these elements, nitrogen, phosphorus, and potassium, mutually influence the intake of one another; for instance, nitrogen, applied in liberal quantities, increases the amount of potassium appropriated by the plant. As I have applied only sodic nitrate as a source of nitrogen, it is possible that this effect may be attributed to the action of the sodium upon the soil. Be this as it may, the amount of potassium appropriated was increased, also the amounts of lime and magnesium, while the amount of phosphorus appropriated by the plant or found in its ash was not influenced. The succulency of the plant was increased, or, put the other way, the amount of dry matter in the plant was decreased. Phosphorus did not appear to exercise any marked influence upon the nitrogen content of the plant; potassium lowered it. Bulletins 208 and 217 treat of these features more fully.

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PURPOSE OF THIS PART OF OUR STUDY

In this part of our study we propose to present the composition of Colorado wheats in general, in so far as it seems to have any purpose, and then to present the results of our study of the effects of these fertilizers, of water, and in some measure, of the weather, upon the composition of wheat. We will leave the question of the milling and baking qualities for future consideration.

The only person, who, to my knowledge, has treated in any way of the composition of Colorado wheats, is Mr. Clifford Richardson, who apparently analyzed samples of wheat grown at this station by Prof. Blount. Mr. Richardson's conclusions are favorable to Colorado as a producer of wheat of high quality. A few quotations from his report are interesting, even if subsequent developments make us wish that the properties of our wheats might measure up more fully to his estimates of them. He says: **"Among the individual states, Colorado sustains the reputation gained in last year's report of producing the finest wheat. . . . . Minnesota, all things considered, probably ranks next to Colorado."*** **"As has been seen. the Colorado wheats are certainly the best which have been produced in this country. For two years they have sustained a high average composition and a large weight per 100 grains. Why do they excel in this manner? It is due somewhat to careful cultivation and selection of seed, but more largely to soil and climate as is proved by the experiments of last year."**

Of thirteen varieties grown by the department and at the Colorado Experiment Station from the same lots of seed Mr. Richardson says: **"In every case the size and general appearance was much improved and, as a consequence, the weight of 100 grains of the crop was much heavier than the seed; in fact, averaged over 26 percent heavier."**

"Of 44 wheats from Colorado, grown during two years, only one fell below 11.5 percent of alubumin and only six below 12 percent."

"Too much confidence, it is seen, cannot be placed on the size and appearance of a wheat or conversely on the chemical analysis alone. When both these elements in its constitution are favorable, then alone can it be pronounced a good wheat."

"The effects upon the composition of grain which we have studied seems to be largely dependent upon the soil, seed and cultivation being the same."†

Dr. H. W. Wiley, in discussing Mr. Richardson's conclusion, says: **"Mr. Richardson was of the opinion, as a result of these studies, that the soil was the most important factor in producing these varieties. A subsequent study of the department, which will be referred to later on**

* Report U. S. Dept. of Agri., 1883, p. 210.
† Report of U. S. Department of Agri., 1883, p. 211.

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seems to show that, in this respect, he was mistaken, and that the soil, as a rule, has the least effect of all the important factors of environment upon chemical composition, provided, of course, that it contains the essential elements of plant food necessary to produce an average crop. The soil, it is true, is one of the most potent factors in determining the size of the crop and the amount of material which is harvested, but it does not have a very marked influence on the chemical composition of the crop produced."*

Dr. Wiley does not call Mr. Richardson's facts into question, only his explanation of them. Mr. Richardson attributes the characters of the wheat to the properties of the soil. Dr. Wiley says that the soil has the least effect of all the important factors of environment upon chemical composition, provided it contains the essential elements of plant food, necessary to produce an average crop.

I know nothing about the views that Mr. Richardson may have adopted subsequently, but these quotations present the question in regard to the part played by the soil and the other environmental conditions as succinctly as any others that I might quote. I think that the greater number of writers on this subject agree in their general attitude with the position indicated by the quotation from Dr. Wiley, which, perhaps, is not so decided as the statements of some others. Dr. J. A. Le Clerc says: "The results so far obtained would seem to indicate that the soil and seed play a relatively small part in influencing the composition of crops."† This is one of the conclusions from their trilocal experiments with wheats.

Schindler, in discussing a wheat climate, says: "We shall have to remind the reader that the climate of the Colorado section is characterized by an extraordinary dryness of the atmosphere and great daily variations of temperature. The relative humidity falls as low as 10 per cent." Then he quotes Hann, Climatology, p. 662: "The advantages of the Colorado climate consist in the clearness of the sky, intense sunshine, and a light atmosphere favorable to evaporation."§

Dr. Le Clerc says, in writing of irrigation: "Where irrigation is practiced, in Colorado for example, ideal conditions for plant growth prevail, for there the sky is clear, the sunshine intense, the air dry. Therefore, if water can be supplied when the crops are in need of it, assimilation will go on at its best and the production of organic substance will be all the more favored. The result will be a large crop of large-sized grain."‡

No author, whose writings I have read, is more insistent upon the very great influence of "climatic conditions" than Schindler, who sets forth strong reasons for his views. Still he acknowledges that soil conditions may produce similar effects. In discussing correlative

* Year Book of the Dept. of Agri., 1901, p. 303.
† Bureau of Chemistry, U. S. Dept. of Agri., Bul. 128, p. 18.
§ Translations by the author.
‡ Year Book U. S. Department of Agriculture, 1906, p. 204.

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variability he says: "The study of the wheat plant in regard to its correlative variability has lead to the conclusion that this can be called into activity, not only by transference to another climate, but also by other extraneous conditions, though climate exercises the greatest influence upon its persistency (Dauer). A change in the character of the soil, be it by change of locality, by manuring, or by cultivation, has a similar action in that the conditions of nutrition are changed and with these the organic efficiency" (of the plant) . . . . . "*

Though Schindler in this way recognized the influence of the soil, still, he scarcely mentions it in the first half of his work, but attributes the greatest influence in determining the character of wheat to the climate. This is, in fact, his thesis.

A paragraph of his relative to Colorado is of sufficient interest to justify its reproduction. After quoting some analyses of Colorado wheats he continues: "I have referred previously to the fact that the cultivation of wheat in this zone (the western plateau and mountain region of the United States) is only possible under irrigation, but which, under the other favorable climatic conditions, yields extraordinary results, as it can be applied at exactly the opportune time. The high yield and weight per kernel is explicable only by this. The relatively high protein content is noteworthy, and is probably dependent upon the characteristics of the soil, which is reputed to be very fertile. The Blount samples excel in this point and suggest that their richness in protein has been forced up by a corresponding application of manure, which is, as is known, easily done. Blount rightly praises the action of sheep manure upon his crops. This was, without doubt, the lever to which he owed his striking results and not his crosses whose influences are difficult to control."†

If the soil has so little to do with the composition and quality of the crops, our wheat ought to be both uniform and good, for our climate is favorable and we have the water supply largely in our control. I think that this statement is true, though the State is large, varies in altitude from 3,000 to 7,500 or even 7,700 feet in the districts where wheat is successfully cultivated, and also in climate. I know of no section, however, of high rainfall. The average annual rainfall at Fort Collins is 14.9 inches and at Grand Junction it is about one-half as much.

I have already stated in Part I of this study that, according to the best information that I can obtain, flour made from Colorado wheat

* Schindler, Der Weizen in seiner Beziehung zum Klima und das Gesetz der Correlation, 1883, p. 138. Translation by the author.

† Schindler, Der Weizen, p. 72. Translation by the author.

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falls from 30 to 40 loaves per barrel behind Kansas and the best Minnesota flours.

This seems to be contradictory to what we should expect, as our summers are usually dry and the days hot. Our spring wheat matures in from 100 to 128 days from planting.

We shall present in the following pages the analytical results obtained in the study of the wheats grown in the seasons of 1913, 1914, and 1915.

The varieties grown were Defiance—a wheat originated at this station by the late Prof. A. E. Blount—Red Fife, and Kubanka. The seed of the last two varieties was obtained from the South Dakota Experiment Station.

The three seasons were very different, and the data pertaining to temperature and rainfall do not convey a very definite idea of the weather conditions that prevailed; nevertheless, I shall give them as furnished to me by Mr. R. E. Trimble, who is in charge of such observations

1913	April	May	June	July	August
Mean Air Temperature	46.1	54.8	63.2	66.8	69.8
Mean Soil Tem. 3"	46.2	58.7	67.9	71.7	74.4
Mean Soil Tem. 6"	46.3	58.8	67.9	72.6	75.2
Rainfall (inches)	1.49	2.09	0.15	2.63	0.41
Cloudy or partly cloudy days	17	21	19	18	11
1914	April	May	June	July	August
Mean Temperature of Air	44.75	54.56	63.58	68.30	66.95
Rainfall inches	3.23	2.73	2.01	1.68	1.28
1915	April	May	June	July	August
Mean Temperature of Air	50.04	50.35	59.62	64.74	62.77
Temperature of soil 3 inches A. M.	45.25	48.96	58.03	63.30	61.00
P. M.	54.62	59.66	69.58	75.10	72.00
Rainfall (inches)	4.01	3.78	1.90	2.12	1.56
Cloudy or partly cloudy days	19	21	15	19	21

This tabulation gives a record of the rainfall, for instance, as accurately as we can read the pluviometers, or the temperature, as accurately as we can read the thermometers, but it does not give us the deciding factors in the development of the wheat. The rainfall up to 12 June in any of the three years was probably without influence upon our crop, as there was at no time a lack of moisture up to this date. On 12 and 13 June, we applied 1 acre-foot of water. This much was necessary, especially in 1913, for with less water we could not get over the ground. A few spots which were not covered, owing to the imperfect leveling, produced only a very light crop of grain. The rainfall in July, 1914, was only 1.68 inches, but 1.45 inches of it fell during a very few davs late in the month and a very good portion of this came in one violent shower, about fourteen days before harvest. This

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rain did apparently but little injury to two of the varieties, but injured the third, especially those plots which had been treated with sodic nitrate, very badly. This rainy period was, of course, accompanied by more or less cloudiness and dewy nights. I have given the number of cloudy days for the months concerned in 1913 and 1915. This simply gives a general and very indefinite measure of the sunshine. These tables, however, give the best meteorolgical data that I have.

The crops for the three seasons are given in the following tabular statement. The bushels are thresher weights; the weight per bushel is for cleaned wheat; and the ratio of straw to wheat is based upon the weights of straw and grain as threshed.

CROP OF 1913

Section	Variety	Fertilizer Pounds per Acre	Bushels per Acre	Weight per Bushel	Ratio of Straw to Wheat
1700	Defiance	Nitrogen 120	34.83	61.00	1.34
1800	Defiance	Nitrogen 80	38.83	60.00	1.17
1900	Defiance	Nitrogen 40	29.00	61.50	1.32
1700	Defiance	Phosphorus 60	28.30	62.00	1.14
1800	Defiance	Phosphorus 40	39.50	62.00	1.29
1900	Defiance	Phosphorus 20	33.83	62.50	1.41
1700	Defiance	Potassium 200	38.50	62.00	1.16
1800	Defiance	Potassium 150	41.66	62.00	1.32
1900	Defiance	Potassium 100	33.00	63.00	1.29
1700	Defiance	Check	41.41	62.00	1.45
1800	Defiance	Check	40.58	62.50	1.57
1900	Defiance	Check	41.33	62.50	1.54
1700	Red Fife	Nitrogen 120	37.08	62.75	1.62
1800	Red Fife	Nitrogen 80	39.91	63.00	1.75
1900	Red Fife	Nitrogen 40	33.81	64.00	1.90
1700	Red Fife	Phosphorus 60	27.83	63.25	1.32
1800	Red Fife	Phosphorus 40	34.00	63.50	1.62
1900	Red Fife	Phosphorus 20	31.29	64.25	1.34
1700	Red Fife	Potassium 200	31.27	63.50	1.35
1800	Red Fife	Potassium 150	33.91	63.50	1.53
1900	Red Fife	Potassium 100	32.83	64.25	1.64
1700	Red Fife	Check	33.16		1.79
1800	Red Fife	Check	32.75	63.50	1.55
1900	Red Fife	Check	33.91	64.50	1.54
1700	Kubanka	Nitrogen 120	41.41	62.75	1.49
1800	Kubanka	Nitrogen 80	39.82	63.00	1.68
1900	Kubanka	Nitrogen 40	39.00	64.00	1.57
1700	Kubanka	Phosphorus 60	32.80	64.50	1.28
1800	Kubanka	Phosphorus 42	39.60	64.50	1.40
1900	Kubanka	Phosphorus 20	32.40	64.25	1.57
1700	Kubanka	Potassium 200	33.80	64.25	1.31
1800	Kubanka	Potassium 150	36.08	64.75	1.51
1900	Kubanka	Potassium 100	30.50	64.50	1.35
1700	Kubanka	Check	34.00	62.50	1.35
1800	Kubanka	Check	34.16	63.50	1.39
1900	Kubanka	Check	34.33	63.50	1.67

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CROP OF 1914

Section	Variety	Fertilizer Pounds per Acre	Bushels per Acre	Weight per Bushel	Ratio of Straw to Wheat
1700	Defiance	Nitrogen 120	25.70	52.00	2.73
1800	Defiance	Nitrogen 80	26.70	56.00	2.53
1900	Defiance	Nitrogen 40	28.50	54.25	2.48
1700	Defiance	Phosphorus 60	33.33	58.00	1.55
1800	Defiance	Phosphorus 40	34.50	58.50	1.64
1900	Defiance	Phosphorus 20	34.00	56.50	1.62
1700	Defiance	Potassium 200	39.16	60.00	1.48
1800	Defiance	Potassium 150	34.33	59.50	1.52
1900	Defiance	Potassium 100	33.33	59.50	1.77
1700	Defiance	Check	32.83	58.25	1.97
1800	Defiance	Check	30.60	56.00	1.99
1900	Defiance	Check	30.00	56.00	1.92
1700	Red Fife	Nitrogen 120	55.50	64.50	1.48
1800	Red Fife	Nitrogen 80	53.00	64.25	1.64
1900	Red Fife	Nitrogen 40	52.33	64.00	1.66
1700	Red Fife	Phosphorus 60	49.33	63.50	1.32
1800	Red Fife	Phosphorus 40	47.66	63.50	1.78
1900	Red Fife	Phosphorus 20	49.33	64.00	1.54
1700	Red Fife	Potassium 200	44.83	63.00	1.54
1800	Red Fife	Potassium 150	45.33	64.25	1.54
1900	Red Fife	Potassium 100	50.33	63.75	1.60
1700	Red Fife	Check	48.60	63.50	1.64
1800	Red Fife	Check	45.70	63.75	1.54
1900	Red Fife	Check	47.33	63.50	1.57
1700	Kubanka	Nitrogen 120	51.66	65.00	....
1800	Kubanka	Nitrogen 80	52.66	64.50	1.53
1900	Kubanka	Nitrogen 40	51.16	64.50	1.53
1700	Kubanka	Phosphorus 60	54.50	64.50	1.37
1800	Kubanka	Phosphorus 40	51.00	65.00	1.44
1900	Kubanka	Phosphorus 20	48.33	65.50	....
1700	Kubanka	Potassium 200	51.16	65.00	1.33
1800	Kubanka	Potassium 150	49.16	65.00	1.49
1900	Kubanka	Potassium 100	43.00	64.50	1.60
1700	Kubanka	Check	52.83	64.75	1.21
1800	Kubanka	Check	46.66	65.00	1.33
1900	Kubanka	Check	44.00	65.00	1.90

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CROP OF 1915

Section	Variety	Fertilizer Pounds per Acre	Bushels per Acre	Weight per Bushel	Ratio of Straw to Wheat
1700	Defiance	Nitrogen 120	8.33	47.00	13.40
1800	Defiance	Nitrogen 80	10.83	47.00	7.00
1900	Defiance	Nitrogen 40	13.70	51.00	4.50
1700	Defiance	Phosphorus 60	21.16	51.00	3.19
1800	Defiance	Phosphorus 40	22.50	50.00	3.96
1900	Defiance	Phosphorus 20	30.40	52.75	2.54
1700	Defiance	Potassium 60	26.83	53.00	3.16
1800	Defiance	Potassium 40	25.33	52.50	2.13
1900	Defiance	Potassium 20	23.50	55.25	3.33
1700	Defiance	Check	20.58	49.75	3.05
1800	Defiance	Check	19.50	49.00	4.43
1900	Defiance	Check	18.50	50.00	2.84
1700	Red Fife	Nitrogen 120	23.33	53.50	3.79
1800	Red Fife	Nitrogen 80	23.66	56.50	4.69
1900	Red Fife	Nitrogen 40	24.50	56.25	3.13
1700	Red Fife	Phosphorus 60	31.33	60.00	3.17
1800	Red Fife	Phosphorus 40	33.00	60.00	2.43
1900	Red Fife	Phosphorus 20	29.50	61.00	3.28
1700	Red Fife	Potassium 200	32.50	61.50	2.28
1800	Red Fife	Potassium 150	33.16	60.25	2.84
1900	Red Fife	Potassium 100	30.83	60.00	2.22
1700	Red Fife	Check	32.33	60.75	3.12
1800	Red Fife	Check	33.61	60.50	2.36
1900	Red Fife	Check	31.00	61.00	3.15
1700	Kubanka	Nitrogen 120	35.50	59.00	2.90
1800	Kubanka	Nitrogen 80	40.83	60.00	3.09
1900	Kubanka	Nitrogen 40	21.91	61.00	2.09
1700	Kubanka	Phosphorus 60	36.50	62.50	2.06
1800	Kubanka	Phosphorus 40	39.75	62.25	2.36
1900	Kubanka	Phosphorus 20	23.75	62.00	2.44
1700	Kubanka	Potassium 200	36.16	62.75	2.55
1800	Kubanka	Potassium 150	34.91	63.00	2.70
1900	Kubanka	Potassium 100	25.01	62.50	3.64
1700	Kubanka	Check	36.25	62.00	2.68
1800	Kubanka	Check	35.16	63.00	3.10
1900	Kubanka	Check	27.00	63.00	2.55

It is scarcely proper to give the ratio of straw to wheat for 1915, for the reason that a very liberal seeding of wild oats was applied with the irrigating water in September, 1914, preparatory to cultivation. There was enough of the wild oats to affect the ratio so seriously as to make it of but little value, still it does not lead us astray in concluding that the ratio in 1915 was not far from twice as high as in the preceding years. The promise for a very large yield was good up to the last week in July, except on the nitrated plots, some of which were badly lodged. About the end of July, due to light rains and cloudy weather, rust attacked all of the plants badly, but injured the Defiance worse than the other varieties. It is my judgment that the effects of this parasite, which were marked, upon the composition of the plant, as is shown in Bulletin 217, were greater than those of the weather.

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An inspection of these data shows some interesting things, especially when taken in connection with the weather conditions. Our table on a previous page shows that we had a rainfall of 2.63 inches during July of 1913, 0.8 of an inch fell on the 18th, and 1.19 inches on the 23rd, which was cloudy all day, otherwise the sky was practically clear during the month and also during August. The yield of the Defiance was a trifle better than that of the other varieties. Its weight per bushel being between 60 and 63 pounds, and the maximum ratio of straw to grain was 1.57. It was surpassed in weight per bushel, but in no other respect by the other varieties. In 1914 we had an excellent season, with only 1,68 inches of rainfall in July. We had a shower on 30 July, during which, 0.87 of an inch of rain fell. This shower was violent and beat down the grain somewhat, especially the Defiance, which was luxuriant and growing rapidly. Rust developed and the grain ripened prematurely. The minimum yield of Defiance fell almost 30 bushels per acre below the maximum for the Fife. Only one plot in the twelve yielded grain weighing 60 pounds per bushel and one plot yielded grain weighing only 52 pounds, while the minimum for the other two varieties was 63 and the maximum 65.5 pounds per bushel. The maximum yield of Defiance was 39.16 and the minimum 25.70 bushels. The maximum yield of the other two varieties was 55.5 and the minimum 43.00 bushels per acre.

The Red Fife and the Kubanka are a little earlier and, perhaps, a little more resistant to rust than the Defiance. These seem to have been the determining factors in this year's crops. In 1915 we did not have so much rain in July as in 1913 but the two seasons were quite different; 1915 was much more cloudy; we had a succession of light rains and the dews were heavy. Rust was bad on all varieties and the Defiance was practically a failure. The biggest yield was 26.8 bushels, weight 53 pounds, the minimum 8.33 bushels, weight 47 pounds. The Red Fife grown with the application of sodic nitrate rusted very badly and yielded only about 24 bushels, weighing 56 pounds to the bushel. Most of the other plots yielded from 30 to 40 bushels, weighing from 60 to 63 pounds per bushel.

THE FACTORS WHICH DETERMINED OUR CROPS

The factors which determined our crops were evidently not the quantity of rainfall but its distribution, the degree of cloudiness, the resistance of the plant to rust, its stage of development when this attack came, the temperature, and the fertility of the soil. The plants grown with the application of nitrates were attacked more severely by

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rust than the others. Whether this was due to the stage of development or to the characters of the tissues may be a question. We have not been able to detect any difference in the date of the ripening of the grain due to the nitrate on the one hand or the phosphate on the other, so the question of development does not press itslf very strongly as accounting for the greater degree in which the nitrate plants were infested. There is an abnormal ripening in the case of plants grown with the application of nitrates, in that the leaves and middle parts of the plants ripen more slowly than the top and bottom, but we have found no difference in the ripening of the grain.

While these cultural results are of great importance in determining the character of the material with which we have to deal, and, unfortunately, complicate our question, they are, after all, incidental, even though their consideration cannot wholly be set aside.

THE CHARACTERISTICS OF COLORADO WHEAT

The first subject that we shall try to consider in regard to Colorado wheat is, whether the composition of the wheat shows anything characteristic.

The wheat grown in the State, even at the present time, is largely spring-wheat, though winter-wheat is being grown in larger quantity than formerly. For this reason I shall present analyses of both spring and winter-wheats. In regard to the samples sent to me from different localities, I can give no details, other than the names and localities furnished me. This pertains only to some of the general samples. These analyses appear on the pages immediately following.

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GENERAL SAMPLES OF SPRING WHEATS—CROPS 1912 AND 1913

	Moisture Percent	Ash Percent	Fat Percent	Fibre Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Defiance, Ft. Collins, Seed used	9.920	1.793	1.818	2.710	2.361	13.458	61.468	1.375	30.66	11.74	8.504	.....	.....
Defiance, La Jara, Yellow-berry, 1912 very bad	10.615	1.686	1.863	2.725	1.454	8.288	64.134	1.409	14.03	6.10	4.221	0.394	0.423
Defiance, Del Norte, Yellow-berry	10.655	1.915	1.835	2.423	1.413	8.054	64.890	1.386	13.73	5.44	4.001	0.434	0.526
Defiance, Ft. Collins, not irr. 1913	11.683	1.680	1.698	2.600	2.444	13.932	62.118	1.046	35.33	13.41	9.707	0.336	0.343
Defiance, Grand Junction, 1912	9.063	1.500	1.670	2.492	2.442	13.917	62.964	0.924	29.73	10.90	8.430	0.271	0.431
Defiance, Clifton, 1912	9.338	1.782	1.855	2.312	2.533	14.440	62.520	1.415	28.47	11.68	8.225	0.329	0.400
Defiance, Ft. Collins, 1911	9.355	1.774	1.588	2.425	2.618	14.923	60.264	1.096	23.30	12.89	9.723	0.376	0.414
Sonora, Del Norte, 1912	10.533	1.731	1.850	2.515	1.974	11.251	63.666	1.561	21.47	8.71	6.082	0.399	0.403
Kubanka, Limon, dry land, 1912 (starchy)	10.235	2.094	1.893	2.455	2.278	12.985	59.490	1.513	30.00	12.49	9.120	0.363	0.440
Kubanka, Ft. Collins, 1912 (starchy)	.....	.....	.....	.....	1.847	10.527	.....	.....	.....	.....	.....	.....	.....
Kubanka, Ft. Collins, 1912 (flinty)	11.200	1.947	1.835	2.525	2.240	12.768	62.046	1.467	25.40	10.79	7.661	.....	.....
Red Fife, Ft. Collins, not irr., 1913	10.495	1.507	1.933	2.525	2.667	15.204	61.686	1.006	38.00	14.83	10.900	0.293	0.357
Red Fife, Ft. Collins, fallowed, 1913	9.138	1.929	1.770	2.620	3.008	17.143	59.076	1.153	40.67	15.58	11.594	0.414	0.380
Marquis, Ft. Collins, fallowed, 1913	9.108	1.861	1.988	2.525	2.807	15.998	59.886	1.266	38.63	15.06	11.042	0.402	0.409
Minn. Spring No. 1, Minneapolis, 1912	8.395	1.923	2.113	2.820	2.248	12.811	63.288	1.215	24.67	9.88	7.524	0.418	0.459
Minn. Spring No. 2, Minneapolis, 1912	8.378	1.819	2.033	2.835	2.212	12.610	62.066	1.175	26.27	10.29	7.843	0.381	0.458
Minn. Spring No. 3, Minneapolis, 1912	8.235	1.823	1.963	2.750	2.139	12.193	63.648	1.278	24.73	9.62	7.182	0.398	0.452
Red Fife, So. Dak. Expt. Sta. Seed used, 1912	10.606	1.749	1.830	2.400	2.249	12.821	59.814	1.215	29.33	11.32	8.225	0.279	0.490
Red Fife, So. Dak. Expt. Sta. Crop, 1913	8.908	1.879	1.860	2.675	2.327	13.265	62.280	1.289	28.43	11.41	8.550	0.321	0.420
Kubanka, So. Dak. Expt. Sta. seed used, 1913	11.023	1.751	1.830	2.265	2.288	13.044	61.182	1.461	30.93	12.91	9.462	0.326	0.468
Kubanka, So. Dak. Expt. Sta. Crop, 1913	8.740	1.857	1.905	2.737	2.336	13.318	60.012	1.478	29.33	12.37	9.223	0.351	0.472
Egyptian, Del Norte	11.199	2.250	1.810	2.462	1.323	7.538	65.610	1.404	*	*	*	0.383	0.666
Durum X Egyptian, Del Norte	10.843	2.032	1.715	2.900	1.575	8.976	63.972	1.198	*	*	*	0.408	0.568

*We could not determine the gluten in Egyptian wheat.

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GENERAL SAMPLES SPRING-WHEATS—CROPS 1912 AND 1913

	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Ratio Gliadin to Glutenin Nitrogen	Total Nitrogen
Defiance, Ft. Collins, seed used	0.0314	0.1678	1.0031	1.0875	1:1.08	2.2898
Defiance, La Jara, 1912	0.0593	0.1328	0.5698	0.6922	1:1.21	1.4541
Defiance, Del Norte, 1912	0.0558	0.1238	0.7084	0.5548	1:0.78	1.4428
Defiance, Ft. Collins, not irrigated, 1913	0.0593	0.2377	0.7049	1.4423	1:2.04	2.4442
Defiance, Grand Junction, 1912	0.0483	0.2028	0.9955	1.1950	1:1.20	2.4416
Defiance, Clifton, 1912	0.0804	0.1958	1.0007	1.2565	1:1.26	2.5334
Defiance, Ft. Collins, 1912	0.0628	0.2377	1.1674	1.1503	1:0.99	2.6183
Sonora, Del Norte, 1912	0.1014	0.1678	0.7327	0.9718	1:1.32	1.9737
Kubanka, Limon, dry land, 1912	0.0699	0.1958	0.9879	1.0244	1:1.04	2.2780
Red Fife, Ft. Collins, not irrigated, 1913	0.0804	0.2587	1.0240	1.6444	1:1.60	3.0075
Red Fife, Ft. Collins, fallowed land, 1913	0.0804	0.2237	1.0659	1.2973	1:1.21	2.6673
Marquis, Ft. Collins, fallowed land, 1913	0.0839	0.2307	1.1417	1.3503	1:1.90	2.8067
Minn. Spring No. 1, Minneapolis, 1912	0.0558	0.2168	0.8203	1.1547	1:1.40	2.2476
Minn. Spring No. 2, Minneapolis, 1912	0.0663	0.2307	0.8564	1.0588	1:1.24	2.2122
Minn. Spring No. 3, Minneapolis, 1912	0.0558	0.1888	0.8063	1.0882	1:1.35	2.1391
Red Fife, So. Dak. Expt. Sta., Seed used	0.0663	0.1958	0.9402	1.0470	1:1.11	2.2493
Red Fife, So. Dak. Exp. Sta. Crop of 1913	0.0314	0.1608	0.8494	1.2855	1:1.51	2.3271
Kubanka, So. Dak. Exp. Sta. Seed used, 1912	0.0628	0.1818	0.9757	1.0581	1:1.08	2.2884
Kubanka, So. Dak. Exp. Sta. Crop of 1913	0.0488	0.1678	0.8040	1.3158	1:1.63	2.3364
Egyptian, Del Norte, 1912	0.1118	0.1238	0.3029	0.7840	.....	1.3225
Durum (Kubanka?)X Egpt. Del Norte, 1912	0.1118	0.1538	0.3751	0.9271	.....	1.5748

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ANALYSES OF GENERAL SAMPLES WINTER-WHEAT—CROPS 1912 AND 1913

	Moisture Percent	Ash Percent	Fat Percent	Fibre Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Turkey Red, Wellington, dry land	10.545	1.988	1.900	2.725	1.929	10.996	62.17	1.355	28.50	10.34	8.020	0.470	0.457
Turkey Red, Wray, dry land	10.155	1.888	1.723	2.487	1.779	10.138	66.04	1.455	20.53	7.87	6.196	0.427	0.456
Turkey Red, La Jara, yellow-berry	10.118	1.867	1.625	2.670	1.446	8.224	66.13	1.341	16.07	6.42	4.603	0.394	0.514
Turkey Red, Las Animas	11.468	1.844	1.540	2.440	2.007	11.441	63.07	1.283	24.63	9.85	7.132	0.471	0.470
Turkey Red, Weckel	9.425	1.493	1.465	2.708	2.335	13.311	64.37	1.272	28.00	10.98	8.463	0.294	0.350
Turkey Red, Clifton	9.708	.....	1.485	2.625	2.286	13.029	61.22	1.427	32.67	12.52	9.405	.....	.....
Kharkov, Ft. Collins	10.423	1.844	1.518	2.700	2.091	11.980	64.15	1.289	25.40	9.72	7.404	0.434	0.460
Kharkov, Ft. Collins	8.848	1.654	1.348	2.337	2.685	15.302	60.95	1.113	38.67	14.00	11.035	0.351	0.385
Jaroslov, Ft. Collins	8.639	1.665	1.360	2.582	2.802	15.970	59.11	1.187	40.73	15.04	11.344	0.362	0.389
Harvest King, Grand Junction, 1912	9.575	1.484	1.778	2.738	2.545	14.508	62.23	1.204	32.17	12.06	8.738	0.327	0.375
Harvest King, Ft. Collins	8.918	1.724	1.740	2.460	2.809	16.012	59.54	1.364	39.80	14.65	11.102	0.398	0.359
Red Cross, Fruita, 1912	9.485	1.481	1.775	2.337	2.483	14.150	63.07	1.404	28.30	11.13	8.271	0.261	0.364
Red Chaff, Eckert	10.743	1.681	1.763	2.677	1.764	10.052	65.54	1.461	21.53	8.57	6.265	0.388	0.416
Fultz, Ft. Collins	9.560	1.641	1.508	2.595	2.866	16.338	59.51	0.957	42.23	14.96	11.666	.....	.....
Big Frame, Ft. Collins	8.755	1.693	1.385	2.735	2.850	16.246	59.69	0.968	42.50	14.62	11.440	0.384	0.366
Prize Taker, Ft. Collins	8.690	1.528	1.878	2.400	2.492	14.206	62.30	1.068	34.50	12.98	9.639	0.306	0.324
Advance, Ft. Collins	8.718	1.672	1.623	2.830	2.674	15.244	60.66	0.870	37.30	14.16	10.694	0.366	0.371
Canadian Hybrid, Ft. Collins	8.630	1.502	1.605	2.475	2.773	16.806	61.63	1.115	38.57	14.35	11.066	0.328	0.369
Minnesota h. w. No. 2, Minneapolis	8.438	1.762	1.795	2.587	1.987	11.324	64.44	1.029	21.73	8.64	6.392	0.379	0.449
Minnesota h. w. No. 3, Minneapolis	8.375	2.092	1.685	2.725	1.887	10.755	64.01	0.924	21.87	8.99	6.686	0.477	0.437

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ANALYSES OF GENERAL SAMPLES WINTER-WHEAT—CROPS 1912 AND 1913

	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Ratio Gliadin to Glutenin Nitrogen	Total Nitrogen Percent
Turkey Red, Wellington, dry land	0.0418	0.1818	0.8390	0.8666	1:1.03	1.9292
Turkey Red, Wray, dry land	0.0418	0.1468	0.4941	1.0958	1:2.22	1.7785
Turkey Red, La Jara	0.0453	0.1398	0.4719	0.7891	1:1.33	1.4461
Turkey Red, Las Animas	0.0628	0.1538	0.7434	1.0472	1:1.41	2.0072
Turkey Red, Weckel	0.0488	0.1748	0.9391	1.1726	1:1.25	2.3353
Turkey Red, Clifton	0.0593	0.1818	0.9192	1.1255	1:1.22	2.2858
Kharkov, Ft. Collins	0.0558	0.1468	0.8250	1.0636	1:1.17	2.0912
Kharkov, Ft. Collins	0.1468	0.1468	0.9529	1.4381	1:1.51	2.6846
Jaraslov, Ft. Collins	0.0593	0.2098	1.1663	1.3664	1:1.18	2.8018
Harvest King, Grand Junction	0.0558	0.2168	0.9880	1.2847	1:1.30	2.5453
Harvest King, Ft. Collins	0.0418	0.1818	1.2163	1.3693	1:1.14	2.8092
Red Cross, Fruita	0.0593	0.2237	1.0311	1.1684	1:1.13	2.4825
Red Chaff, Eckert	0.0628	0.1588	0.6642	0.8827	1:1.33	1.7635
Fultz, Ft. Collins	0.0663	0.2168	1.2105	1.3727	1:1.13	2.8663
Big Frame, Ft. Collins	0.0558	0.2168	1.2862	1.2915	1:1.00	2.8503
Prize Taker, Ft. Collins	0.0418	0.1748	0.9554	1.3202	1:1.38	2.4922
Advance, Ft. Collins	0.0349	0.1818	1.0068	1.3508	1:1.34	2.6743
Canadian Hybrid, Ft. Collins	0.0558	0.1888	1.0952	1.4332	1:1.31	2.7730
Minn. h.w. No. 2, Minneapolis	0.0314	0.1748	0.7003	1.0802	1:1.54	1.9867
Minn. h.w. No. 3, Minneapolis	0.0384	0.1888	0.7592	0.9005	1:1.18	1.8869

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GENERAL SAMPLES FOR 1914

Spring Wheats	Moisture Percent	Ash Percent	Fat Percent	Fibre Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Defiance, Eckert, yellow-berry very bad.....	9.313	1.892	1.858	3.095	1.974	11.252	64.638	1.452	28.37	12.49	8.093	0.433	0.597
Defiance, Ft. Collins, fallow, wet in shock....	8.428	1.708	1.933	3.555	2.075	11.825	60.822	1.063	31.33	13.30	9.293	0.322	0.393
Defiance, Ft. Collins, fallow, not wet.....	8.465	1.643	2.018	3.512	2.113	12.044	62.064	1.068	32.00	12.99	9.076	0.326	0.430
Marquis, Ft. Collins, fallow, wet in shock....	8.965	1.508	2.140	3.257	2.419	13.788	59.148	1.065	40.83	16.44	11.393	0.333	0.340
Marquis, Ft. Collins, fallow, not wet.....	8.460	1.448	2.165	3.320	2.468	14.065	60.210	1.157	40.40	16.40	11.589	0.338	0.364
Red Fife, Ft. Collins, fallow, wet in shock....	8.985	1.813	2.015	3.292	2.492	13.477	58.728	1.099	42.17	16.24	11.398	0.332	0.377
Red Fife, Ft. Collins, fallow, not wet.....	8.184	1.588	2.015	3.447	2.596	14.794	60.486	1.241	43.20	16.90	11.781	0.350	0.503
Winter Wheats													
Red Chaff, Eckert, yellow-berry very bad....	9.855	1.587	2.145	3.062	1.411	8.043	64.458	1.352	17.63	7.20	4.935	0.367	0.535
Turkey Red, Fruita, yellow-berry in all.....	10.215	1.647	1.540	2.940	1.693	9.647	64.638	1.068	24.37	10.06	7.063	0.345	0.561
Turkey Red, Fruita, yellow-berry in all.....	9.213	1.566	1.610	2.952	1.765	10.050	65.250	1.215	26.66	10.67	7.750	0.309	0.539
Turkey Red, Fruita, no yellow-berry.....	8.675	1.295	1.633	2.956	2.318	13.210	61.740	1.142	37.60	15.49	11.313	0.231	0.485
Big Frame, Ft. Collins, wet in shock.....	9.053	1.626	1.480	3.122	2.509	14.301	59.976	1.241	42.00	15.95	11.672	0.359	0.477
Fultz Mediterranean, Ft. Collins, wet in shock	9.460	1.601	1.583	2.960	2.457	14.002	61.106	1.184	42.00	16.31	11.909	0.364	0.504
Prize Taker, Ft. Collins, wet in shock.....	9.488	1.633	1.843	2.862	2,286	13.031	60.570	1.263	37.50	14.32	10.853	0.371	0.484
Harvest King, Ft. Collins, wet in shock.....	9.298	1.648	1.713	2.605	2.270	12.936	62.262	1.356	41.63	16.28	11.455	0.376	0.483
Jaraslov, Ft. Collins, wet in shock.....	9.305	1.503	1.793	2.912	2.631	14.994	59.040	1.031	48.83	18.15	13.488	0.333	0.465
Kharkov, Ft. Collins, wet in shock.....	9.485	1.615	1.460	2.875	2.446	13.942	59.886	1.003	44.90	16.19	11.822	0.346	0.534

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GENERAL SAMPLES SEASON 1914

Spring Wheats	Amid Nitrogen Percent	Alubmin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Ratio of Gliadin to Glutenin Nitrogen	Total Nitrogen Percent
Defiance, Eckert, yellow-berry, very bad	0.0769	0.1888	0.7712	0.9371	1:1.21	1.9740
Defiance, Ft. Collins, fallowed ground, wet in shock	0.0384	0.2098	0.9728	0.8535	1:0.88	2.0745
Defiance, Ft. Collins, fallowed ground, not wet	0.0384	0.2098	1.2577	0.6171	1:0.49	2.1130
Marquis, Ft. Collins, fallowed ground, wet in shock	0.0488	0.2517	1.1954	0.9231	1:0.79	2.4190
Marquis, Ft. Collins, fallowed ground not wet in shock	0.0523	0.2587	1.2012	0.9553	1:0.79	2.4675
Red Fife, Ft. Collins, fallowed ground, wet in shock	0.0523	0.2587	1.1169	1.0636	1:0.95	2.4915
Red Fife, Ft. Collins, fallowed ground, not wet	0.0558	0.2517	1.0812	1.2067	1:1.12	2.5955
Winter Wheats						
Red Chaff, Eckert, yellow-berry very bad	0.0769	0.1538	0.4543	0.7260	1:1.20	1.4110
Turkey Red, Fruita, all affected with yellow-berry	0.1188	0.1608	0.6175	0.7954	1:1.45	1.6925
Turkey Red, Fruita, no yellow-berry	0.0769	0.2098	1.0787	0.9521	1:0.88	2.3175
Turkey Red, Fruita, all affected with yellow-berry	0.1188	0.1678	0.6781	0.8003	1:1.19	1.7650
Big Frame, Ft. Collins, wet in shock	0.0804	0.2307	0.9868	1.2111	1:1.23	2.5090
Fultz Mediterranean, Ft. Collins, wet in shock	0.0593	0.2307	1.1383	1.0282	1:0.90	2.4565
Prize Taker, Ft. Collins, wet in shock	0.0699	0.2447	1.0811	0.9803	1:0.82	2.2860
Harvest King, Ft. Collins, wet in shock	0.0558	0.2656	1.2723	1.0368	1:0.82	2.6305
Kharkov, Ft. Collins, wet in shock	0.0628	0.2377	1.1301	1.0154	1:0.90	2.4460

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MINERAL CONSTITUENTS OF WHEAT—GENERAL SAMPLES OF 1912 AND 1913

	Sp. gr.	SiO_2 Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	Total P Percent	Inorganic P Percent	Organic P Percent	Total N Percent
Red Fife, not irrigated and not fertilized, Ft. Collins, 1913	1.4383	0.116	0.012	present	0.050	0.129	0.357	0.002	.....	0.105	0.293	0.025	0.268	2.700
Defiance, not irrigated and not fertilized, Ft. Collins, 1913	1.4317	0.053	0.009	present	0.042	0.138	0.343	0.008	.....	0.093	0.336	0.015	0.321	2.444
Harvest King, winter wheat, Fruita, 1912	1.4165	0.026	0.007	present	0.038	0.116	0.375	?	0.087	0.101	0.327	0.020	0.307	2.545
Defiance, 4½ miles east of Fruita, 1912	1.4055	0.034	0.009	present	0.033	0.119	0.431	0.007	0.118	0.141	0.271	0.012	0.259	2.442
Defiance, Clifton, 1912	1.4327	0.038	0.007	present	0.029	0.141	0.400	?	0.165	0.155	0.329	0.015	0.314	2.534
Red Cross, 2½ N.E. of Fruita, winter wheat	1.4237	0.038	0.007	present	0.025	0.120	0.364	0.009	0.086	0.175	0.261	0.014	0.247	2.483
Red Fife, So. Dak. Expt. Sta. (Seed Wheat), 1912	1.4127	0.018	0.005	0.005	0.044	0.134	0.490	?	0.072	0.133	0.279	0.011	0.268	2.248
Kubanka, So. Dak. Expt. Sta. (Seed Wheat), 1912	1.4334	0.011	0.006	0.005	0.026	0.141	0.468	?	0.064	0.145	0.326	0.012	0.314	2.282
Defiance, fallowed ground, Ft. Collins, 1912	1.4298	0.009	0.005	present	0.043	0.150	0.414	0.020	0.060	0.157	0.376	0.017	0.359	2.618
Red Fife, fallowed ground, Ft. Collins, 1913	1.4352	0.007	0.007	present	0.037	0.162	0.380	0.020	0.059	0.146	0.414	0.025	0.389	3.008
Marquis, fallowed ground, Ft. Collins, 1913	1.4334	0.006	0.007	present	0.041	0.155	0.409	0.023	0.056	0.132	0.402	0.022	0.380	2.804
Minnesota, Hard Spring No. 1, 1912	1.4195	0.029	0.005	0.006	0.044	0.135	0.438	0.008	0.071	0.128	0.418	0.027	0.391	2.248
Minnesota, Hard Spring No. 2, 1912	1.4049	0.018	0.004	0.006	0.027	0.149	0.439	0.025	0.076	0.144	0.381	0.026	0.355	2.213
Crop of 1914														
Defiance, Ft. Collins, cultivated fallow one year	1.3619	0.016	0.006	0.005	0.037	0.150	0.393	0.009	0.192	0.127	0.322	0.009	0.313	2.075
Marquis, Ft. Collins, cultivated fallow one year	1.3984	0.012	0.005	0.005	0.036	0.130	0.340	0.028	0.081	0.162	0.333	0.014	0.319	2.419
Red Fife, Ft. Collins, cultivated fallow one year	1.4259	0.018	0.005	0.007	0.030	0.147	0.377	0.028	0.119	0.184	0.332	0.015	0.317	2.547

I have given the analyses of general samples of spring- and winter-wheats in the preceding tables in order to convey a general idea of what the composition of Colorado wheats really may be. Some of the samples analyzed were from Minnesota; these have been introduced simply for comparison. It is true that I could have found analyses of Minnesota wheats, but I wanted analyses made by the same analyst, to eliminate personal equations. The South Dakota samples are introduced because we used their crops of 1912 as seed wheats. Their samples of the 1913 crop were obtained to see how their crops for this year compare in composition with the preceding, as well as with our own. I do not know how the seasons differed in South Dakota nor how they differed from ours, besides, our wheats were grown with, and theirs without irrigation.

I fully realize that it is almost useless to try to compare wheats grown in different localities, as the composition evidently depends upon so many conditions that cannot be given in the statement of the analyses, that differences in the composition cannot readily be interpreted. As an illustration of this, the three samples of Turkey Red wheat given in the table of winter-wheats, General Samples of 1914, serve very well. These are samples labeled "Fruita", which I personally collected. Two of these samples were grown within one-half mile of one another, while the third sample was grown a short distance east of these in the same district. I was informed that these growers received seed from the same lot. These three samples were produced under the same conditions of weather; they were all threshed directly from the field. The grains were all protected from the weather, in fact were stored in granaries and they were all grown with irrigation. I do not know definitely, but I think it quite safe to assume, that they were grown with one irrigation, and without any fertilization. So far, the conditions under which the three samples were grown may be considered as identical and yet their composition is very different. This is not only the case with the protein, which is 9.6, 10.1 and 13.2 percent respectively, but we find the phosphorus and potassium varying to a significant extent, but inversely with the protein content. Were it not for my personal knowledge of the soil conditions, and of the other conditions as well, the analytical results obtained in these cases would be impossible of interpretation. This pertains to all general samples with much force. I am so fully convinced that it is wholly useless to try to interpret an analysis of a wheat, without a rather full knowledge of the conditions under which the sample was grown, that I have sought no general samples during the past year and a very few in the past two years. As a further justification for this conviction I may cite the case of two samples given in the table of general samples of spring-

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wheats for 1913 and a sample of Red Fife to be given in a subsequent table, all grown in 1913 under identical conditions of weather and irrigation and within less than 100 feet of one another on two contiguous and uniform plots of land. We have in the first pair, Red Fife, protein 17.143; Marquis, protein 15.998. The third one is a sample of Red Fife with 13.442 percent of protein. The differences in the amounts of phosphorus and potassium present are, again, big, and roughly, inversely proportional to the protein present. I shall endeavor to explain these differences in the proper place.

It becomes a question what the value of an analysis of a general sample of wheat, as a representative of the product of a county or a state, may be. It is only by the intelligent selection and analysis of a very large number of samples that a reasonably accurate estimate of the quality of the product of a good-sized county can be obtained. In our table of general samples of spring-wheats, rejecting the Egyptian, we have a range of protein from 8.224 to 17.143 percent and of true gluten from 4.001 to 11.593 percent. These figures represent different varieties, but we find for the same variety a range from 4.001 to 9.723 percent of true gluten calculated on the air-dried wheat. These differences correspond to a wide range of conditions of climate, soil, and very probably of cultivation. In the San Luis Valley, for instance, we have an altitude of 7,500 feet with its own peculiar climate and soil, and at Fort Collins we have an altitude of 5,000 feet with its climate and soil. While the San Luis Valley is 2,500 feet higher than Fort Collins, it is about 200 miles further south. The San Luis Valley has a rainfall of about 7.0 inches and the Fort Collins section one of 14.9 inches. Neither section as a rule can grow spring-wheat without irrigation. The wheats produced cannot be compared in regard to composition unless all of the conditions are given with the samples.

The Minnesota samples, analyses of which are given in the preceding table, were kindly sent to me, on request, by Mr. G. H. Tunell of the Minnesota Grain Inspection Department. I desired to see samples of their grading and also to have our own analyses of these wheats, because the high quality of their flours, made from hard spring-wheats is, I believe, universally recognized. I, however, know nothing of the conditions under which they were grown and we do not know to what extent these samples are comparable to ours, or are representative of Minnesota wheats. I am not certain about the variety, but I would judge this to be Red Fife. So far as analytical results are concerned these samples are not equal to the majority of the Colorado samples. We have only two of the general samples of Colorado wheats which appear to be of materially lower quality than these Minnesota samples,

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and these two are samples of Defiance wheat grown at La Jara and Del Norte in the San Luis Valley. Both of these samples represent extreme cases of yellow-berry or mealiness and are, for this reason, perhaps, inferior to the Minnesota samples which are flinty wheats.

I have already stated in another place that the Minnesota flour is preferred by our bakers for bread-making, as it yields from 30 to 40 more loaves per barrel than our own. Assuming these samples of wheat to be representative, this opinion is contrary to the analytical results. At the present time I am inclined to accept the bakers' judgment as the more reliable criterion. The differences in the amounts of the mineral substances in the wheats are so small that it is difficult to interpret them, though they, without doubt, are significant. The range in phosphorus, for instance, in the thirteen cases in which we have given the mineral constituents, is equal to 0.151 percent of the air-dried wheat, but this is 60 percent of the minimum amount of phosphorus found in these samples and indicates a great difference in the nutrition of the plants.

While the value of general samples, without a definite statement of the conditions under which they were grown, may be small in the way of indicating the general character of the wheat grown in any considerable section of the country, still, they may have a little value in showing the range in composition. It is for this reason that I have given the 50 odd analyses of general samples, including 5 samples from Minnesota and 4 from South Dakota. The South Dakota samples were introduced for the further reason that we used their wheat of the 1912 crop as seed in our experiments.

WHAT ANALYSES SHOW

These analyses show that our wheats often contain large percentages of nitrogen and also that the true gluten is high. They are even richer in these substances than our samples' from the other two states. Further, that the ratio of gliadin nitrogen to glutenin nitrogen falls well within the limits accepted for good flours. On the other hand these samples show that some of our wheats are low in nitrogen, but these have a fairly good gliadin-glutenin ratio. This may have no more than an analytical significance, but this is all that we, at the present time, care to consider, as we intend to divorce composition and quality as far as possible in this bulletin. It may well be that these are so intimately related that they ought not to be considered separately, still our purpose is to confine our consideration to the composition of our samples and the factors that affect it, leaving the question of quality for a subsequent time.

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There are only a few samples among those given, which were grown on "dry land", or without irrigation, but, so far as we can attach any value to so small a number of samples, we find no justification for the claim which is sometimes made, that dry land wheat is better, i.e., richer in nitrogen than irrigated wheat. This sentence is written with the knowledge that it is opposed by the views of very competent men either directly or by intimation. Schindler, for instance, holds that hot, dry summers produce wheats high in nitrogen as compared with the same variety grown in cooler and wetter summers or localities. This seems to be, at least it is accepted, as an established fact, but it is not applicable to our conditions, concerning which we shall have more to say at another time.

The general samples of wheat from the same locality, as well as from different localities, are readily separated into classes according to their flintiness or starchiness. The flinty kernels, on the one hand, are rich in nitrogen, the starchy ones, on the other hand, are poorer in nitrogen. I do not know when or by whom this observation was first made, but it is a very widely recognized property of wheat kernels. Ritthausen and Dr. R. Pott mentioned such kernels in 1872 * and this condition is described quite fully by Schindler in his "Getreidebau"† where he says: "'Flinty' wheat is, on account of its greater density, i.e., its high specific gravity, designated hard wheat and is, as a rule, richer in nitrogen, and the amount of gluten is greater than in the mealy, or so called soft wheats" to which he adds in a footnote "This is also the case even when the flinty and starchy kernels are of the same variety and have been produced in the same field; in this case, the kernels produced in the top and bottom portions of the head are apt to be more flinty and those in the middle portions more mealy. P. Holdefleiss§ found that in one and the same crop of Early Bastardweizens the flinty kernels contained 1.907 percent nitrogen (12.23 percent protein) the mealy ones, on the contrary, 1.566 percent nitrogen (9.79 percent protein)."

The physical property of the kernels first mentioned is not characteristic of any locality, but is found distributed everywhere throughout the State, so far as my knowledge of the wheats produced extends. We find, that the chemical composition varies with this, but this does not prove that the bread-making qualities are lessened, though the gluten content certainly varies, as well as the chemical composition. There is no doubt but that physical properties and chemical composition are dependent upon conditions of fertility which vary from place to place in small areas and even more in large ones, especially in a State of

* Die landwirtschaftlichen Versuchs-Stationen Band XVI, p. 391.
† Schindler, Der Getreidebau, 1909, p. 151.
§ P. Holdefleiss, "Mehligkeit und Glasigkeit der Weizenkoerner," "Kuehns Berichte," XIV, 1900.

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such varied physical conditions as we have in Colorado. It is not only a question of climate, especially of rainfall and seasonal differences due to altitude, but also a question of soil. The soil of the San Luis Valley, for instance, is very different from that of the Arkansas Valley, or of the Grand Valley, in its origin and in its properties. The climates, too, of these valleys are very different. The San Luis Valley has an altitude of 7,500, the Grand Valley about 4,000 and the eastern portions of the Arkansas Valley about 3,000. They differ further in this, that the San Luis Valley is surrounded by high mountains. The range on the east side of it, the Sangre de Cristo, is very high, possibly the highest in the State. Mount Blanca, its highest peak, attaining a height of 14,467 feet, while Las Animas, in the Arkansas Valley, is some 140 miles east of the mountains in the plains section and approximately 4,500 feet lower. Irrigation is necessary in both sections.

No reasonable number of general samples grown under such a variety of conditions, including both soil and climate, can give any definite information concerning the character of the wheat grown in the State. The only thing that would be feasible, would be to study the grain produced in some definite section whose conditions of soil and climate could be given. I, at first, thought that it might be possible for us to obtain enough samples from reliable parties to accomplish this broader purpose in a reasonably satisfactory manner. It would serve no good purpose to give all of the considerations which have lead us to abandon this notion. Those given must satisfy the reader, as they have sufficed to convince us that it is wise on our part to acknowledge our change of attitude. The facts stated give our reasons for presenting so few general samples in 1914 and none in 1915. Further, they explain why we have confined our efforts to the study of our own samples grown under fairly well known conditions.

YELLOW-BERRY

It will be noticed that the samples of Defiance from various localities differ by a maximum of 6.859 percent of protein or 1.206 percent of nitrogen. The physical properties of the kernels indicated a very decided difference in these samples; those from La Jara and Del Norte present large, plump, mealy kernels, that from Del Norte weighing 49.07 grains per 1,000 kernels. There were no flinty or part flinty kernels in this sample. It is an extreme case of yellow-berry wheat. The sample from Fort Collins presents smaller, somewhat shrunken, flinty kernels which weigh 30.65 grams per 1,000; in the former sam-

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ple we have 8.054 percent protein (N x 5.7) and in the latter 14.923 percent. In the La Jara sample, with 8.288 percent protein, the kernels are smaller than in the Del Norte sample. There are a few berries which cannot be classed as either flinty or mealy, though the berry is uniform in appearance. This is not the case in many other samples, for in these the kernels show distinct areas of mealiness, sharply contrasting with the flinty character of the rest of the kernel. This condition is not confined to any one variety of either spring or winter-wheats. We have previously mentioned the differences in composition of three samples of a winter-wheat, Turkey Red, for which we gave the protein as 9.6, 10.0 and 13.2 percent, showing a difference of 3.6 percent in the protein present. These samples were grown, according to my information, from the same lot of seed and in the immediate neighborhood of one another—the second and third samples within one-half mile of one another. The physical properties of these samples are just as distinct as are those of the Defiance samples previously given.

It seems proper to consider this subject in this connection, because it is the most patent condition occurring in our general samples, corresponding to a marked difference in composition. Kosutany, Schindler, and such other European writers as I have read, do not formulate a definite cause for this condition, though they repeatedly refer to it. The general explanation which runs through Schindler's book, "Der Weizen in seinen Beziehungen zum Klima," is that it is dependent upon climate, particularly upon moisture. On page 76 of the work just mentioned he says:* **"The processes of carbohydrate formation, as well as the deposition in receptacles for the same, depend in the highest degree upon climatic factors, but the soil, the only source of nitrogen for the cereals, is the first of all (factors) in the (formation) of protein. The absolute quantity of protein in wheat depends upon this (the soil supply) and can be regulated by the application of nitrogen, but the relative amount is determined by the climate."** This author has previously stated, page 41: **"However fragmentary the cited material may be, one fact of fundamental significance is shown thereby, i.e., that the absolute weight of wheat (weight of 1,000 kernels) stands in a definite, independent relation to the external conditions of growth, among which, climate excels all others in influence."** These quotations suffice to show that the author considers climate as the most important factor in determining the ratio between the protein and carbohydrates in the wheat kernels. While this author designates kernels as flinty, mealy, and half mealy, he does not definitely state that climate causes mealiness, but he says, as quoted above,

* In the quotations from Schindler I have given the title and page of the German work but not the text. The translation is the author's.

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that the relative amount of nitrogen is determined by the climate. Lawes and Gilbert, in an article entitled, "Our Climate and Our Wheat-Crops",* quote from a preceding article which appeared in the Journal of the Royal Agricultural Society of England Vol. IX, Part 1, p. 96: "Thus it is obvious that different seasons will differ almost infinitely at each succeeding period of their advance, and that with each variation the character of development of the plant will also vary, tending to luxuriance, or to maturation, that is, to quantity or to quality as the case may be. Thence, only a very detailed consideration of climatic statistics, taken together with careful periodic observations in the field, can afford a really clear perception of the connection between the ever fluctuating characters of season and the equally fluctuating characters of growth and produce. It is, in fact, the distribution of the various elements making up the season, their mutual adaptations, and their adaptation to the growth of the plant which throughout influence the tendency to produce quantity or quality. It not infrequently happens, too, that some passing conditions, not indicated by a summary of the meteorological registry, may affect the crop very strikingly; and thus the cause will be overlooked, unless observations also be made and the stage of progress and tendencies of growth of the crop itself at the time, be likewise taken into account." This article reviews the weather conditions and the wheat crops in England from 1816 to 1879, but more particularly from 1843-44 till 1878-79. During the latter period they select six seasons during which the yield of straw and grain were both high, four seasons with high yield of grain and low yield of straw, and four seasons during which the total produce was low. They give the total number of rainy days, i.e., days on which 0.01 inch or more of rain fell. With 140 rainy days the yield of both straw and grain was high. With 136 rainy days the yield of grain was high, of straw low. With 199 rainy days the total produce was low. In discussing the wheat crop of 1878-79 at Rothamsted, one of the poorest crops on record at that time, they had 226 rainy days, with 42.29 inches of rainfall. In comparing the two very bad seasons of 1816 and 1879 these authors conclude: "Lastly, it would appear that any defect of our climate in appropriateness for the production of full and well-matured wheat crops is more connected with an excess of rain and consequent wetness of soil and humidity of atmosphere, than with any deficiency of average summer temperature." In regard to the yield of grain in 1879, it appears from the data given that it was about one-half of the average crop for the preceding 27 years. In regard to quality, the weight per bushel seems to have been taken as the measure. In fact, so far as I can gather, they use the terms "quality" and "weight per

* Rothamsted Memoirs, Vol. V. 11th Article, p. 4, or Journal Roy. Ag. Soc. Eng. Vol. XVI, s. s. Part I, p. 178.

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bushel" synonymously. The weights per bushel given for the season of 1879 range from 2.7 to 5.4 pounds below the average for wheat grown under the same conditions of manuring for the preceding 27 years. That this is what is understood by quality in this case, seems apparent from the manner in which they refer to it. They say: **"The defect in weight per bushel of the dressed corn was great under all the conditions cited."**

"Lastly, great as was the deficiency in the produce of corn, and in the weight per bushel of dressed corn, under all the conditions, the proportional deficiency of straw was much less."

After discussing the conditions under which the crop of 1878-79 was grown they add: **"Thus, the plant, which luxuriates in a comparatively dry soil and climate passed its whole existence under exactly opposite conditions; and the result was only what was to be expected."**

"It has of course long been known that an excess of wet is injurious to the wheat crop, but it is only comparatively recently that one at least of the material causes of the adverse influence has been made out; namely, the great loss of nitrogen carried off by drainage in the form of nitrates."

These authors clearly hold that the weather conditions, especially the mean temperature and rainfall, exercise a big influence upon the yield and quality of wheat, meaning by quality, primarily, weight per bushel. They further assign as one cause of this, the removal of nitrates by the leaching action of excessive rainfall. The same authors return to this subject in a subsequent article "On the Continuous Growth of Wheat, etc., from 1864 to 1883".*

"We find the two crops running a parallel course, showing great differences in their yield as the seasons are favorable or unfavorable. The Rothamsted soil, like a great many cultivated soils, contains a large amount of mineral food of plants: it also contains organic nitrogen, that is to say, nitrogen in combination with carbon, the residue of previous vegetation. This organic nitrogen does not appear to be available as food for the wheat plant, but every year a certain amount of it is converted into nitric acid, which combines with the lime in the soil. In this state it is very soluble in water, is readily washed out of the soil by heavy rain, and, further, is a most important and essential food of the wheat plant."

"The amount of nitric acid formed each year will vary, the formation being the most rapid in the hottest weather, provided the soil is sufficiently moist. The amount of nitric acid which the wheat crop can take up will also vary, and in a cold and wet winter much will be washed beyond the reach of the roots of the plants."

* Rothamsted Memoirs, Vol. VI., 3rd Article, p. 44. This originally appeared in the Jour. Roy. Ag. Soc. Eng. Vol. XX, s. s. Part. II.

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"These facts, which are of universal application, enable us to explain some of the causes which tend to the production of good or bad crops of wheat."

In discussing the good crops of 1858 and 1863, they go further in discussing the general composition of the grain than in the preceding quotations and give us another view of how the weather affects this. In the preceding quotations they speak of good and bad crops without special consideration of the composition of the grain, but in the following quotations they include the latter: "It will afterward be seen, indeed, that the total crop of 1863 contained about one and one-half time as much mineral matter per acre, and also considerably more nitrogen than that of either of the other seasons (1852, 1856, 1858): yet the percentage of both was much lower in the grain, and that of the nitrogen lower also in the straw, than in the produce in either of the other years. There is here again evidence that with favorable maturation there is low percentage of both mineral matter and nitrogen; that is, favorable maturation means the greater accumulation of non-nitrogenous organic substances, carbohydrates and especially starch,—the result necessarily being a lowering of the proportion though not of the actual amount of both the nitrogenous and mineral constituents." These authors have been quoted already as attributing the defect of their climate, in regard to the wheat crop, to an excess of rain rather than to a deficiency in the mean temperature. They attribute the effects of excessive moisture to two principal facts, first, to the preference of the plant itself for a dry rather than a wet soil, and second, to the leaching out of the nitrates.

Lawes and Gilbert, it appears, have written exclusively of winter-wheat which, in England, seems to have a very long growing period, as they speak of August as their harvest period. They make no distinction between flinty and mealy kernels, as the German writers do. I am unfortunately not familiar with the English wheats and have seen but few samples of European wheats, but the Swedish, Dutch and French wheats that I have seen were mealy wheats and that to such an extent that one could not distinguish the kernels as having distinct characteristics, as flinty and mealy. This may be the case with the English wheats, but one would scarcely think that it would be the case with all of their samples, which were grown with such a variety of manuring. Still, they use the weight per bushel as indicative of quality; the only exception to this statement is in the quotation just made defining favorable maturation, "That is, favorable maturation means the greater accumulation of non-nitrogenous organic substances,—carbohydrates and especially starch,—the result necessarily being a lowering of the proportion, though not of the actual amount of both the nitrogenous and the mineral constituents." Even in this statement it is not clear that their statement can be construed as distinguishing between flinty and mealy

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wheats. I am inclined to think that it is a general statement without distinction of any special physical properties. The principal point in all of this, however, is evident, that they consider the weather conditions as determining the quality and quantity of their crops.

I believe that all of the publications upon this subject that have appeared in this country have adopted the same general views, to which, in a certain measure, we must subscribe, for it is evident, without statement, that the growth of the plant and the quality of the product is dependent in a measure upon weather conditions, i.e., upon accidental conditions from year to year. There are, however, some characteristics of the grain which are neither determined nor obliterated by the weather conditions, though they have been very largely attributed to the latter. Kosutany and also Schindler attribute, in an indefinite way, influence to the soil, but the latter, especially, attributes a predominating influence to the climate, and he uses the term in its larger sense.

The writers in this country go, perhaps, even farther in attributing to climatic influences, a determining influence upon the character of the grain produced. I would like to mention all of these writers but there are too many of them. The only one among them who, so far as I know, attaches any considerable influence to soil fertility is Snyder, formerly of Minnesota. The views of the great majority of the rest of these writers are represented by the statements of Le Clerc of the Bureau of Chemistry of the U. S. Department of Agriculture in Bulletin 128, from which the following quotations are made: "Eckenbrecher* grew six varieties of barley in twelve different localities and found that the same variety showed a much larger variation in nitrogen content and in weight per 1000 grains when grown in the twelve localities than the six varieties did when grown in any one locality, that is, that climatic conditions, or environment, exerted a greater influence than did the seed or even the variety. Yet Hall in the article just quoted† makes the statement that variety is the chief factor in affecting the composition of plants, that each race or variety possesses characteristics which are modified only to a relatively slight extent by soil, seed, or climate".§

"Bogdan found that an increase of salt content of alkali soils produced an increase in the nitrogen and ash content of wheat though the absolute amount of these constituents decreased due to the fact that the grains were smaller. This, in a certain way, explains the good quality of the rather small grains of wheat grown in southeastern Russia, northwestern America, Hungary etc., where the soil is rich in soluble salts, especially nitrates. It has, however, generally been assumed that fertilizers influence the yield

* Wockenschrift Brau, 1907, 24-491.
† Science 1905-22-461.
§ Bul. 128, Bureau of Chemistry, U. S. D. A., p. 8.

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considerably and to a small extent the composition. In like manner, soil is one of the lesser factors affecting the composition of wheat. This is the opinion of Lawes and Gilbert, Hall, Wiley, and others; though, of course, a nitrogen-rich soil will yield a crop of a somewhat greater nitrogen content than will a nitrogen poor soil."*

The conclusions reached in this bulletin may be taken as reflecting the opinion of, at least, a very large percentage of our writers. They are formulated as follows:

"Wheats of the same variety when grown in the same locality and under the same conditions are, therefore, seen to vary but little in composition although coming from seed differing widely in physical and chemical characteristics. These results are corroborative of Eckenbrecher's work with barley and are entirely at variance with Hall's statement that each race or variety possesses qualities which are modified only to a slight degree by seed, soil, or climate. Wheat of any one variety, from any one source and absolutely alike in chemical and physical characteristics, when grown in different localities, possessing different climatic conditions, yields crops of very widely different appearance and very different in chemical composition. The results so far obtained would seem to indicate that the soil and seed play a relatively small part in influencing the composition of crops."†

These quotations from Le Clerc may be taken as fairly representative of the views generally obtaining among our writers on this subject. The terms climatic conditions and environment are not used with such definiteness that one can always tell just what is meant, in fact they are sometimes used as alternative expressions of climatic conditions or environment. Again, the latter term is used in a more comprehensive sense, taking in rainfall, sunshine, temperature, winds, humidity of the air, soil, time of planting, cultivation, manuring, thickness of seeding, previous crops, etc.

I have deemed it wise to state these general views which are very commonly held by students of this subject.

THE EFFECT OF CLIMATE ON COMPOSITION

The explanation that I have offered for yellow-berry in wheat is not in harmony with the statements just made, nor are they in harmony with other explanations offered, which belong to several classes; for instance, the result of injury by fungi, unseasonable harvesting and exposure to the weather after cutting, to heredity or a "tendency" herit-

* Bul. 128, Bureau of Chemistry, U. S. D. A., p. 9.
† Bul. 128, Bureau of Chemistry, U. S. D. A., p. 18.

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able in wheat, and to climatic conditions. Under the latter head I suppose the principal factor considered is the rainfall or supply of water. Again, I know of no one more explicit in his statements than Le Clerc, who discusses with clearness flinty and mealy wheats. He says: **"Furthermore the wheat of the humid regions contains a larger percentage of mealy kernels showing that there is a very close relation between the percentage of protein and the percentage of flinty grains, that is, generally, the more flinty the kernels the higher is the percentage of protein. An excessive amount of rainfall or irrigation is almost always accompanied by a crop containing a low percentage of protein. This is further shown in the work done in 14 different localities in the far Western states, 7 of these places were irrigated and the percentage of protein averaged 12.1 while in the 7 places where no irrigation was practiced the protein content of the wheat was 15.4 percent."*** In the next paragraph he describes two samples of wheat of which he says: **"The non-irrigated samples consisted of flinty kernels entirely and contained 5.4 percent more protein than the original seed and 6.6 percent more protein than the irrigated sample. The irrigated sample contained, moreover, very few flinty kernels (only 20 percent)."** Again, in commenting on the observations of Lawes and Gilbert he writes: **" 'The six seasons of bad crops showed rain to have fallen during each of the 199 days. The seasons of good crops had but 136 days during which it rained."†** **The probable reason for such differences is that an excessive rainfall dilutes the nitrates in the soil too much and there being but small amounts of carbohydrates in the process of formation, owing to lack of sunshine, less protein is formed. The result is a mealy grain of low protein content."§** In the same article is given excellent illustrations of flinty, half-flinty and mealy kernels and in the legends we find "Flinty wheat grain grown under dry farming", "Starchy wheat grain grown under excessive irrigation". If there were any doubt remaining in regard to what the author considered the cause of the mealiness of some kernels this would remove it.

TOO MUCH IMPORTANCE ATTACHED TO CLIMATE

In Bulletin 205 I showed that this condition is not due to injury by fungi, nor to the time of cutting, nor to weathering, nor to climatic conditions, etc. The answer to these suggestions is given by pointing out the fact that we can produce flinty kernels by applying nitrates or increase the percentage of mealy berries by increasing the supply of potassium. While I do not for one moment doubt the importance of favorable weather conditions in the production of a good crop of wheat, I am convinced that too much importance has been attributed to this group of agents over and against the influence of the soil con-

* Yearbook, U. S. D. A., 1906, p. 203.
† Yearbook, U. S. D. A., 1906, p. 205.
§ There were 199 and 136 days respectively on which 0.01 inch or more of rain fell. These are the mean number of days for each period.

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ditions. While there is no doubt but that lack of sunshine and excessive moisture, especially as rainfall, influence the composition of the wheat kernel, it is probably seldom the case that it goes so far as to determine the flintiness or mealiness of the kernel, or if it does, it is probably by its direct influence upon the food supply in the soil in washing the nitrates below the feeding area of the plant roots, rather than by its direct action upon the plant itself. There is no doubt but that these agents, frequent rains and cloudy weather, have a direct influence upon the plant which follows from the data given in our Bulletin 217, but it is not so great nor in the direction assigned to it in these quotations. We shall further give some data to show that it is difficult to remove enough nitrates by the application of water to produce the effects attributed to it, and it is for this reason that I have just said that it is probably seldom the case that it goes so far as to determine the flintiness or mealiness of the kernel. This effect of excessive rain, the washing out or reducing the amount of nitrates in the soil, was pointed out by Lawes and Gilbert in their article "Our Climate and Our Wheat-Crops" and again, in the article "On the Rain and Drainage Waters of Rothamsted".

I wish in this connection to emphasize the statement previously insisted upon that analytical results obtained with samples of wheats unaccompanied by a full account of all of the conditions under which they were grown are too difficult of correct interpretation to justify reliance upon any interpretation offered for such analytical facts. In this connection I appreciate that the conditions under which the crops of which Lawes and Gilbert wrote, grew, were wholly different from those under which my samples were grown. They wrote of winter-wheat which seemingly had a growing period, i.e., from planting till harvest, of ten months or more. My observations have been made, principally, on spring-wheats with growing periods varying from 101 to 128 days. The rainfall given for 1878-79 at Rothamsted is 42.29 inches. The average annual rainfall at Fort Collins is 14.9 inches, in the exceptional year of 1915 it was about 22.5 inches. The rainfall during the total growing period of our spring-wheat is usually about 7 inches; in 1915 it was a little over 13 inches. Our mean temperature for the growing period is higher than the mean temperature under which their crops were grown. It would seem to be unnecessary to state these facts, but it is, perhaps, wise to do so lest it be thought that I failed to consider them.

EFFECTS OF NITROGEN AND PHOSPHORUS ON FLINTINESS OR MEALINESS

In Bulletin 205 I aimed to do exactly what is suggested by its title, to point out the cause of flintiness and mealiness in our grains

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and to show how this can be controlled. We did not enter into a study of the flinty and mealy berries themselves, in fact, we gave no analytical data, but confined ourselves to the direct results of field experiments, using one-tenth-acre plots. These results showed that the percentage of flinty berries was materially increased, practically to the complete elimination of the mealy berries, by the application of nitrogen in the form of nitrate. Further, that the application of potassium increased the percentage of mealy kernels, and gave to all of the kernels a less desirable appearance than the wheats produced on the check plots. I could not convince myself that phosphorus had any perceptible influence on this condition. The only analytical data given in this bulletin pertained to the main features of the soil and sub-soil in regard to the supply of plant food.

The positive and conclusive character of the proof adduced to show the cause of these characters in wheat kernels seemed to render any discussion of the chemical properties of the kernels themselves entirely unnecessary and only a few explanations, for the most part physical, were considered.

At the time I wrote Bulletin 205, I knew of but few observations similar to those I had made. The principal ones were the observations of H. von Feilitzen (Abs. Expt. Sta. Record, Vol. XVII, p. 24), F. Moertlbauer (Abs. Expt. Sta. Record, Vol. XXV, p. 33) and a private communication from Prof. A. Keyser. Quite recently, a year subsequent to the publication of Bulletin 205, I found an article published by Ritthausen and Dr. R. Pott in Die Landwirthschaftlichen Versuchs Stationen, Vol. XVI, 1873, pp. 384-399, in which identical conclusions are given, except in regard to the effects of potassium, namely, that nitrates produce small, flinty, hard kernels; and that phosphorus is without effect upon the flintiness or mealiness of the kernels. The two series of experiments are identical in plan and results, in so far as the experiments are co-extensive. I would gladly have cited these experiments made at Poppelsdorf in 1872, had I known of them at the time that I wrote Bulletin 205, as the results obtained under the conditions obtaining in the lower Rhine district in 1872 are identical with those obtained at Fort Collins in 1913 and 1914. Their observations on the effect of nitrates upon the wheat kernels, in comparison with other fertilizer, are of sufficient interest to justify their quotation in this place. These observations are:

"The variety used for seed was one which had been cultivated for a long time at Poppelsdorf. The kernels were flinty, hard and dark colored; kernels of any other character could not be found even on examining a larger quantity.

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"The grain from the unmanured plots Nos. 1, 7, and 12 were mostly half-mealy or transitional, light colored, large and plump with smooth and lustrous surface; even the flinty kernels showed this latter characteristic.

"The grain from plots Nos. 4, 8, and 11 manured with superphosphate and phosphoric acid showed exactly the same characteristics, but varied more in size; the number of small, mostly flinty (glassy) kernels was apparently equal to that of the large ones.

"The nitrogenous fertilizers,* Nos. 2, 5, and 9 produced only small, but well-formed, thoroughly hard; flinty and dark colored kernels.

"The kernels obtained from the mixed manuring, Nos. 3, 6 and 10, were like those in the case of pure nitrogenous manuring, all small, hard, flinty and dark, together with no small number of shrunken and imperfectly formed kernels."

Ritthausen and Dr. R. Pott give the nitrogen contained in these grains; the maximum for the check plots was 2.78 percent, that for the phosphoric acid plots was 2.77, that for the nitrogenous manure 3.48, and that for the mixed manuring was 3.82 percent. The moisture in the samples was practically the same, the maximum variation in 12 samples given being about 0.8 percent.

FLINTY KERNELS HIGHER IN NITROGEN

It is not specifically stated in the article that the flinty kernels are higher in nitrogen than the mealy ones, but it evidently can be inferred that this is so. This, however, is generally stated to be a fact. Schindler has been quoted on a previous page as stating "This is also the case even when the flinty and starchy kernels are of the same variety and have been produced in the same field.... P. Holdefleiss found that in one and the same crop of early Bastardweizen the flinty kernels contained 1.957 percent of nitrogen (12.23 percent protein), the mealy ones on the contrary 1.566 percent nitrogen (9.79 percent protein)". The difference in the nitrogen content of flinty and starchy kernels is so thoroughly well established that it is almost, if not altogether, common knowledge. It is also quite as well known that the nitrogen content of the grain can be increased by the application of sodic nitrate or ammonium sulfate. We have so far, then, the following facts pertaining to the effects of nitrogen in the form of nitrates or an easily nitrifiable form of nitrogen; it affects the size of the kernel, tending to produce a small or even shrunken Grain;† it produces a high degree of flintiness and with this a dark,

* The nitrogenous fertilizers used were sodic nitrate and ammonic sulfate.

† A similar observation is made in regard to the effect of nitrates in producing shrunken kernels in Ohio Bul. 243, p. 587, and illustrated on p. 572, showing 60 percent of shriveled kernels.

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vitreous appearance, and a higher content of nitrogen. Further, we have the fact that kernels of this character are produced in the same variety of wheat, in the same field and during the same season alongside of large, plump, mealy, light-colored, soft kernels, sometimes even much lower in their nitrogen content. It would seem evident that these results cannot be the result of any climatic conditions, even if we narrow this term down to those accidental features which constitute weather conditions. We can support this view with data of our own collecting. On the other hand, we have our direct observations that potassium increased the percentage of yellow-berry, the size of the kernel, its plumpness, and imparts to it a lighter color. In the summary of Bulletin 243 of Ohio we find this conclusion: "Potassium has increased the proportion of plump kernels, although the yield is the same as when nitrogen is applied to the soil and the composition is practically the same as that found in the wheat from unfertilized soil."* I have a few samples of Ohio wheats, which fact I owe to the courtesy of the Ohio Station, and these samples are so different from our wheats that comparisons are scarcely permissible. But one thing is very striking and this is that they are strongly affected with yellow-berry, or starchiness, and are not comparable with ours in plumpness. I take it that this enhances their observation relative to the effects of potassium upon this characteristic of the kernel. As I am almost wholly ignorant of the conditions under which these samples were grown, I would not, if I desired to do so, permit myself to judge of the causes of the characteristics of these samples further than the author has done.

THE DIFFERENCE IN COMPOSITION OF FLINTY AND STARCHY KERNELS

The physical differences between the flinty and starchy berries are very evident to the eye, much more so than can be expressed in words. We have stated that such berries differ in composition. The annotations in the tables, giving the composition of general samples, are intended to suggest an idea of the composition of yellow-berry wheat, and the table given herewith is intended to show the differences in the composition of these berries grown on our own plots under identical conditions of climate, including the water supply and known conditions of manuring, the soil being as nearly identical as can be obtained. The table contains no samples grown with the application of nitrogen, because these samples contained no mealy kernels. Analyses of such samples will be found in subsequent tables and may also be found in the tables of general samples of winter-wheats for 1914.

* Ohio Bulletin 243, p. 587.

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ANALYSES OF YELLOW-BERRY AND FLINTY KERNELS GROWN UNDER IDENTICAL CONDITIONS

Variety	Fertilizer Per Acre		Moisture	Ash	Fat	Fiber	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten
Red Fife,*	60 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.568	8.928	66.042	1.108	18.38	7.91	5.748
		Flinty	.....	.....	.....	.....	1.881	10.720	61.110	1.034	22.66	9.85	7.032
Red Fife,	40 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.469	8.374	65.286	1.012	17.75	7.77	5.538
		Flinty	.....	.....	.....	.....	1.772	10.100	62.712	0.995	21.98	9.55	6.685
Red Fife,	20 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.525	8.692	64.665	1.081	18.05	7.75	5.535
		Flinty	.....	.....	.....	.....	1.712	9.756	63.904	1.029	21.78	9.22	6.486
Red Fife,	200 lbs. potassium,	Yellow-berry	8.410	.....	2.105	3.125	1.640	9.348	65.826	1.425	19.23	8.21	5.937
		Flinty	8.348	.....	1.960	3.020	1.949	11.105	61.505	1.449	24.97	10.37	7.497
Red Fife,	150 lbs. potassium,	Yellow-berry	9.310	.....	2.008	2.920	1.600	9.117	65.952	1.016	19.23	8.21	5.914
		Flinty	9.365	.....	1.853	2.912	1.891	10.776	63.378	1.046	23.68	10.10	7.385
Red Fife,	100 lbs. potassium,	Yellow-berry	.....	.....	.....	.....	1.658	9.448	64.764	1.046	19.92	8.57	6.209
		Flinty	.....	.....	.....	.....	1.894	10.796	64.188	1.034	26.00	10.48	7.579
Kubanka,	60 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.583	9.023	63.468	1.260	18.85	8.31	5.867
		Flinty	.....	.....	.....	.....	1.811	10.320	62.640	1.232	24.42	10.48	7.290
Kubanka,	40 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.514	8.627	65.547	1.289	19.72	8.62	5.947
		Flinty	.....	.....	.....	.....	1.778	10.131	62.766	1.255	24.38	10.34	7.321
Kubanka,	20 lbs. phosphorus,	Yellow-berry	.....	.....	.....	.....	1.598	9.105	63.918	1.386	21.32	9.16	6.366
		Flinty	.....	.....	.....	.....	1.884	10.739	60.390	1.438	26.97	11.45	8.054
Kubanka,	200 lbs. potassium,	Yellow-berry	8.923	.....	2.113	2.995	1.564	8.910	65.502	1.278	21.47	9.24	6.398
		Flinty	9.068	.....	1.923	2.907	2.044	11.648	62.186	1.260	27.73	11.86	8.380
Kubanka,	150 lbs. potassium,	Yellow-berry	.....	.....	.....	.....	1.629	9.279	65.070	1.409	22.40	9.65	6.653
		Flinty	.....	.....	.....	.....	2.057	11.725	63.792	1.467	28.60	12.25	8.697
Kubanka,	100 lbs. potassium,	Yellow-berry	.....	.....	.....	.....	1.628	9.279	64.641	1.415	21.85	9.33	6.368
		Flinty	.....	.....	.....	.....	2.000	11.400	62.120	1.432	27.30	11.88	8.455
Kubanka,	None	Yellow-berry	.....	.....	.....	.....	1.587	9.046	65.848	1.210	21.23	9.31	6.448
		Flinty	.....	.....	.....	.....	1.921	10.947	61.812	1.278	27.53	11.87	8.425
Kubanka,	None	Yellow-berry	.....	.....	.....	.....	1.599	9.111	62.820	1.560	19.97	8.79	6.160
		Flinty	.....	.....	.....	.....	1.969	11.223	62.118	1.432	27.52	11.88	8.423
Kubanka,	None	Yellow-berry	9.113	.....	2.230	3.010	1.610	9.174	63.918	1.259	20.57	9.28	6.373
		Flinty	9.430	.....	2.010	2.835	1.936	11.092	62.172	1.369	26.33	11.58	8.193

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DISTRIBUTION OF NITROGEN PERCENTAGE IN YELLOW-BERRY AND FLINTY WHEAT

Variety	Fertilizer Per Acre		Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen	Total Nitrogen
Red Fife,	200 lbs. potassium,	Yellow-berry	0.0523	0.2028	0.6561	0.7288	1.6400
		Flinty	0.0523	0.2028	0.7166	0.9768	1.9485
Red Fife,	100 lbs. potassium,	Yellow-berry	0.0488	0.1888	0.6409	0.7210	1.5995
		Flinty	0.0488	0.1958	0.7667	0.8792	1.8905
Kubanka,	200 lbs. potassium,	Yellow-berry	0.0453	0.1958	0.7096	0.6128	1.5635
		Flinty	0.0523	0.2098	0.7260	1.0554	2.0435
Kubanka,	no fertilizer	Yellow-berry	0.0349	0.1818	0.6921	0.7007	1.6095
		Flinty	0.0663	0.2168	0.8424	0.8105	1.9360

*In the case of the Red Fife, the kernels were so generally affected by the yellow-berry that it was almost impossible to sort out a sample of flinty berries which were even for the most part entirely free from the affection, so that, in the end, it was not a question of flinty and yellow-berry kernels, but of very badly and of very slightly affected kernels selected from the same sample of wheat.

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ASH CONSTITUENTS OF YELLOW-BERRY AND FLINTY WHEAT

Variety, Kubanka.....Yellow-berry Fertilizer, per acre....150 lbs. Potassium		Flinty 100 lbs. Potassium	Flinty 120 lbs. Nitrogen
	Percent	Percent	Percent
Silica, SiO_2	0.008	0.022	0.012
Iron, Fe	0.003	0.004	0.004
Manganese, Mn	0.003	0.004	0.005
Calcium, Ca	0.032	0.032	0.032
Magnesium, Mg	0.140	0.140	0.133
Potassium, K	0.444	0.408	0.418
Sodium, Na	0.041	0.022	0.016
Chlorin, Cl	0.123	0.118	0.093
Sulfur, S	0.093	0.103	0.128
Phosphorus, P (total)	0.394	0.394	0.343
Inorganic, P	0.011	0.011	0.008
Organic, P	0.383	0.383	0.335
Nitrogen, N	1.629	2.057	2.168
Specific Gravity	1.3976	1.4363	1.4241

The above results are given in percentages of the air-dried grain.

THE RATIO OF PROTEIN TO STARCH

As the protein and starch make up about 75 percent of the air-dried wheat, they must bear an inverse relation to one another, i.e., if the percentage of protein is higher it must be largely at the expense of the percentage of the starch. We find that this is, in a measure, true of our results, but it is not so great or regular as we would expect. We see that the total nitrogen is higher in the flinty berries; and this fact persists throughout the analyses for all the forms of nitrogenous substances determined. It is rather surprising that this is shown in the case of the Red Fife samples, for, as the footnote states, the distinction between flinty and starchy kernels in this case was difficult to make. The Kubanka was more easily sorted into two distinct classes. In the case of the check samples, we find that there is a difference of roughly, 0.32 percent of nitrogen in favor of the flinty berries; in the case of the samples grown with phosphorus 0.26 percent; and in the case of the samples grown with the application of potassium, 0.45 percent. We find for the true gluten a difference of 1.4 percent in favor of the flinty kernels in the case of phosphorus fertilization; 2.0 percent with potassium, and 2.0 percent in the case of the check plots. This is not the place to consider the character of the gluten, but it may be stated in a tentative and general way that this feature of the wheat is in favor of the starchy kernels. The glutenin-nitrogen is regularly higher in the flinty kernels.

The total ash is not given in the table, only the mineral, or ash-constituents in the air-dried grain. There are some differences suggested by the results given; the principal one is that the starchy wheats are higher in potassium than the flinty ones.

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THE EFFECT OF IRRIGATION ON MEALINESS

Le Clerc attributes mealiness or starchiness in some instances, at least, to irrigation. He says: "It is almost always the case that irrigation tends to produce a mealy grain, although in several instances it has been noted that even under irrigation the grain has kept its flinty character. This is explainable only on the theory that the irrigation has not been excessive."*

Irrigation Had No Effect On Mealiness In Our Experiments

I do not think that this thesis can be maintained, for I have samples of dry-land wheat, winter-wheat of course, in which mealy berries are predominant, constituting 85 percent of the sample. Further, I have samples grown with the same amount of irrigation, which differ greatly in the proportion of mealy kernels present, from less than 20 to nearly 100 percent. The amount of water received during the whole life period of the plants was the same, in one year 21 and in another 19 inches, these are certainly not excessive quantities of water, especially if received as water of irrigation. Further, I have grown wheat with 19 and 31 inchs, four plots in each of two successive years. The total supply of 31 inches was at least 12 inches in excess of that required to produce a maximum crop. This excessive amount was applied on 12 July, shortly after the grain had set, and at a very great risk to the crop, for had we had a slight shower accompanied by wind, the grain would have gone down and been severely injured. The effect of this irrigation on the development of yellow-berry, or mealiness of the kernels was nil. If there be any difference in the samples of the different varieties treated in this manner, it is in favor of the heavier irrigation. These samples have been analyzed, and there are no differences that can be attributed to the difference in the amount of irrigating water applied. The four plots used in this case were checks, and had received no fertilizer, so they are thoroughly comparable with the other checks.

Through the kindness of Mr. Don. H. Bark, now with the Canadian Pacific Railroad, but formerly with the U. S. Department of Agriculture, I received a set of six samples grown under controlled conditions in regard to water applied and fertilization. The variety is Marquis. I will not give the analyses in this place, but simply state that the water applied to six one-tenth-acre plots varied from the rate of 1 to 3 feet per acre. The time from planting till harvest was 122 days; the time from the first till the last irrigation was 102 days, during which two of the six plots received 12 inches of water, two 24 inches, and two 36 inches each per acre. So far as the mealiness of these

* Yearbook U. S. D. A., 1906, p. 205.

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samples is concerned, no differences are to be noted. Fortunately for our present purposes they are badly affected by yellow-berry and, apparently, equally so. It is scarcely possible that 1 foot of water applied in three applications distributed over 102 days was materially more than a necessary quantity, and yet the mealy berries are just as abundant in this wheat as in that that received 3 feet of water.

It may be well for me to state that in my own experiments I could not see that the second irrigation, applied on 12 July about 30 days before harvest, did either good or harm; it appeared to be entirely indifferent so far as my crop was concerned, and was worse than useless, because, I thereby exposed my crop to unnecessary risks of damage by wind. The growth of the plants was already luxuriant, and had only a slight shower, accompanied by wind, occured while the ground was as soft as a foot of water could make it, all manner of evils would have followed.

There is another very important feature connected with the samples Mr. Bark furnished me, i.e., three of the plots had received a heavy dressing of farmyard manure, sixteen loads to the acre, but I could not see that this had changed the character of the wheat. It increased both the amount of straw and grain, but had very little or no effect upon the character of the grain.

Irrigating Water and Rainfall May Have Entirely Different Effects

So far as mealiness and flintiness of the berries are concerned, the amount of water applied, up to 3 feet in 102 days, is without effect. I will digress to anticipate the discussion of our 1915 results to the extent of stating that *water applied to the ground in irrigation and water applied to the plant in the form of frequent light rains produce altogether different results.* Our crops in 1913 and 1915 are very different though they were grown with the same fertilization and the same amount of water, 19 inches in each case. In the former year we applied 12 inches of water and had 7 inches of rainfall, in the latter year, we applied 6 inches of water and had 13 inches of rainfall. The results are interesting, as we shall see when we come to discuss them, but so far as the question at present under consideration is concerned, they were practically without effect, which sustains my contention that these characteristics of the wheat kernel are dependent neither upon the weather nor the water applied, but upon the soil.

We have now, in addition to the facts adduced in Bulletin 205, the facts that berries grown on the same ground, under the same conditions of weather, differ in physical and chemical properties. Neither the weather nor water supply can be appealed to to account for this difference; wheat grown as dry-land wheat may be as badly affected by

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mealiness as wheat grown with irrigation. Water applied to the soil up to 3 acre-feet in 102 days does not produce mealiness to any greater extent than 1 acre-foot, or than may occur in dry-land wheat. It is shown, further, that when the water is applied to the plant in a succession of light rains very marked effects may be produced upon the composition of the plant and the grain, but the question of flintiness and mealiness, and the characteristics of such kernels, remain unaffected.

MEALINESS CAUSED BY TOO HIGH A RATIO OF POTASSIUM TO AVAILABLE NITROGEN

It was stated in Bulletin 205 that the cause of mealiness was an unfavorable ratio of potassium to available nitrogen, which, for the wheat plant, is equivalent to nitric-nitrogen. By unfavorable ratio of potassium in this case is meant one which is too high. Just what too high a one is we have not determined, but in our soil the application of 40 pounds of nitrogen in the form of sodic nitrate at the time of seeding spring-wheat is sufficient to change the product from a light colored one, in which plump, mealy berries, low in nitrogen are abundant, to one in which the berries are smaller, possibly shrunken, flinty, translucent, and richer in nitrogen. How much washing with irrigating water it may take to remove this nitrate beyond the reach of the plant and prevent its production of flinty grains has not been determined. Two feet of water, one applied on 12 June the other on 12 July, plus 7 inches of rainfall during the season, will not suffice to do it, nor will 6 inches of irrigating water plus 13 inches of rainfall prevent its producing flinty berries, even when no lodging takes place. Further, it has not been determined how small a quantity of nitrogen applied in this form may produce this effect, nor has it been determined at what period in the development of the plant its application will produce the most favorable result. We have demonstrated that application of nitrates made four weeks later still affect the growth of the plant, and further, that 80 pounds of nitrogen applied in two equal dressings four weeks apart will almost certainly do injury by lodging the straw, shrivelling the wheat, and inducing an attack of rust.

In Parts I and II of this study we have given much attention to the moisture, and also to the nitrates in the soil, their distribution, and the rate of their formation, because of their importance in this connection.

There is another view of the yellow-berry subject which connects it still more intimately with our experiments. This is the question whether the composition of flinty berries, such as is produced by the application of nitrogen as sodic nitrate, is desirable or not, which we will consider after we have given further data pertaining to our crops.

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THE CRUSHING STRENGTH OF WHEAT

After explaining that flinty and mealy wheats differ in their structure, in that the mealy kernels contain air-filled spaces which reflect the light and cause the berries to appear white and opaque, and that the flinty berries, owing to the absence of such air-filled spaces, permit the passage of the light and therefore appear translucent or flinty, Schindler says that the flinty berries are designated as hard wheats and the mealy ones as soft wheats.* This is the clearest definition of these terms that I have met with, but they are not generally used with the sharp distinction of this definition. Attempts have been made to determine the degrees of hardness of different wheats and use the figures obtained as a means of classification. At the California Station they determined the weight necessary to cut the kernels when they were placed between the jaws of a pair of pinchers.† At the Kansas Station they used a "Grain Tester" devised in conjunction with Wm. Gaertner & Co., of Chicago, in which they determined the weight necessary to crush the kernels when placed under a steel pestle in a miniature mortar.§ On page 374 of Kansas Bulletin 167, Prof. Roberts gives the following basis of classification. **"In general we find that 'soft' wheats crush under a pressure of 6,000 grams or less (13 pounds), semi-hard wheats at about 9,000 grams (20 pounds) and hard wheats at 12,000 grams and over (26 pounds and over).**

OUR METHOD OF DRYING

Prof. Roberts dried his samples for seven days at the boiling point of water under ordinary atmospheric pressure and preserved them in a desiccator till used. I dried our samples at 100° C., under a pressure of 75 mm. for 7 hours, corked the bottles tightly and preserved them in a desiccator. The object in this drying is to bring all of the samples to a common basis in regard to moisture, but it is a question whether there is any need of doing this, for the variation in moisture at a given locality is not great and this factor adjusts itself if wheat is transported from one place to another, and the tests are all made at the place of grading. There seems to be a more serious question raised by drying than the variation due to the moisture in the wheat, i.e., does drying at 100° C., for seven days leave the wheats in such a condition that the determination gives us the real crushing strength of the sample, or only that which it may chance to show under a purely artificial condition? Even this would not be a serious objection if we could be sure that all samples deported themselves in a similar

* Schindler, Der Getreidebau, 1909, p. 151.

† California Bul. 212, G. W. Shaw and A. J. Gaumnitz, p. 335.

§ Kansas Bul. 167, H. F. Roberts, "A Quantitative Method for the Determination of Hardness in Wheat."

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manner under this treatment, for then, we could determine how much the crushing strength was decreased or increased by the drying and could make the proper addition or subtraction as necessary if deemed advisable. We have taken 36 groups of 350 kernels each, in all 12,600 kernels. Eighteen sets were dried as stated and 18 others were used in their air-dried condition. Air-dried, in our case, indicates about 10.0 percent of moisture in the wheat. The results are given in the following tabular statement:

CRUSHING STRENGTH OF SOME COLORADO WHEATS

	Air-dried	Oven-dried
Red Fife, received no irrigation	.....	8.358
Defiance, received no irrigation	9.112	13.356
Harvest King, Grand Junction	.....	7.420
Defiance, J. B. Hunter	.....	7.496
Defiance, Red Cross Ranch, Clifton	.....	11.886
Red Cross Winter Wheat, Fruita	.....	7.188
Minnesota Spring No. 1	.....	9.548
Minnesota Spring No. 2	.....	9.094
Defiance, Agricultural College, Ft. Collins	.....	12.367
Red Fife, Agricultural College, Ft. Collins	.....	9.905
Marquis, Agricultural College, Ft. Collins	.....	10.464
Red Fife, South Dakota Experiment Station	.....	7.909
Kubanka, South Dakota Experiment Station	.....	16.569
Defiance, Sect. 1800, 80 lbs. of nitrogen	10.087	10.623
Defiance, Sect. 1800, 40 lbs. of phosphorus	10.938	11.860
Defiance, Sect. 1800, 150 lbs. of potassium	11.042	12.759
Defiance, Sect. 1800, no fertilizer	11.190	12.048
Red Fife, Sect. 1800, 80 lbs. of nitrogen	11.212	10.263
Repeated	10.653	10.476
Red Fife, Sect. 1800, 40 lbs. of phosphorus	10.711	9.898
Repeated	10.235	10.184
Red Fife, Sect. 1800, 150 lbs. of potassium	10.678	9.946
Repeated	10.365	10.043
Red Fife, Sect. 1800, no fertilizer	10.971	10.082
Repeated	10.314	10.422
Kubanka, Sect. 1800, 80 lbs. of nitrogen	15.839	19.111
Kubanka, Sect. 1800, 40 lbs. of phosphorus	15.505	18.517
Kubanka, Sect. 1800, 150 lbs. of potassium	15.495	17.225
Kubanka, Sect. 1800, no fertilizer	15.354	19.122
Defiance, Sect. 1900, 100 lbs. of potassium, yellow-berry	8.218	9.197
Defiance, Sect. 1900, 100 lbs. of potassium, flinty	10.351	13.644
Kubanka, Sect. 1800, 150 lbs. of potassium, yellow-berry	.....	13.056
Kubanka, Sect. 1800, 150 lbs. of potassium, flinty	.....	18.234
Red Fife, Sect. 1800, 150 lbs. of potassium, yellow-berry	.....	7.734
Red Fife, Sect. 1800, 150 lbs. of potassium, flinty	.....	9.469

COLORADO WHEATS ARE SEMI-HARD TO HARD

According to the results obtained and adopting the suggested standard of classification, our wheats are semi-hard to hard. The Minnesota samples would be classed as semi-hard, while our Defiance would be classified as a hard wheat. My understanding of the situation is that our Defiance is classed by the millers as a soft wheat, and while

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the flour made from it is white and very pleasing to the eye, it is not a good bread-making flour, as it only makes from 250 to 260 loaves to the barrel.

In the case of the Defiance and also of the Kubanka, we find that drying as described, causes an increase of from 1,000 to about 3,000 grams in the crushing strength of the kernels, but in the case of the Red Fife, we find that drying has lowered the crushing strength. Of course, we base all statements on the assumption that 350 kernels, taken without choice, is sufficient to give us a close approximation to the average crushing strength of the samples. This number is adopted from the Kansas bulletin. We were surprised in the first place that the Red Fife should show a lower crushing strength than the Defiance, in the second place that its crushing strength should be lowered by the drying instead of raised, as in case of the other two varieties. It will be noticed that the whole series of experiments with the Red Fife was repeated, and that the second series corroborated the results of the first.

Further, these two series agree as closely as we have any right to expect them to agree. Feeling that I might be prejudiced in my results, i.e., the discrepancy between my results and the public estimate of the wheats experimented with, I requested a friend who is proficient in this kind of calculation to analyze the data given in the Kansas bulletin and see how closely their groups would agree; the results were more disconcerting to me than my own figures, and I am inclined to allow a variation of plus or minus 300 grams or more for single groups of 350 each. They, of course, may come much closer if the wheat is very uniform, which is seldom the case, as is evident on the most casual observation of our mixed wheats. The variation which may be found in individual samples, due to the flintiness or mealiness of the kernels, is indicated by the last six samples given in the second column of the table, or eight including the last two samples in the first column. This group of samples is given to show the difference in the crushing strength of flinty and mealy or yellow-berry kernels selected from the same sample, and consequently grown on the same soil under the same conditions of cultivation and climate. This difference for Defiance, dried at 100° C., is, in round numbers, 4,500, and in the air-dried condition 2,100 grams, and for the Kubanka, dried at 100° C., 5,200 grams. The difference shown by the table between the flinty and mealy kernels in the Red Fife sample, 1,700 grams, is altogether as significant as the greater differences found for the other varieties, because the sample grown with the application of 150 pounds of potassium was so badly affected by this condition that the selection of a flinty sample was exceedingly difficult, and the separation was

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only partially successful. One must acknowledge, however, that no one of the 21 samples of this variety tested showed more than a medium degree of hardness, according to this test. The maximum crushing strength, 11,212 grams, is found in the air-dried sample grown with the application of 80 pounds of nitrogen. This sample is to all appearances an unexceptional one.

PLANT'S NOURISHMENT INFLUENCES CRUSHING STRENGTH

Whether the result of classification by this method corresponds to the milling or flour-making qualities of the wheat or not, it serves to show according to the table given, that the plant's nourishment actually influences the crushing strength of the average kernel, and that yellow-berries are more easily crushed than the flinty ones. This is a conclusion at which one arrives with just as satisfactory a degree of certainty by crushing the berries between his teeth, but this method gives no measure of the difference. The differences in the cases given in the table, vary, from 1,400 to 5,000 grams, in favor of the flinty berries, and if a variation of 200 or even 300 grams from the true average exists, it scarcely lessens the value of the result, for it is only an approximation to the true average.

The results obtained with the Defiance samples, would seem to contradict all that we have affirmed concerning the effects of nitrates upon this feature of the kernels. An examination of the samples, however, suggests a ready explanation for the results. The sample grown with the application of potassium, consists of light-colored, plump kernels with a very low percentage of mealiness, while that grown with the application of nitrogen, consists of dark-colored, small, and to a large extent, badly shrunken kernels, so that the results given by the testing machine are just what one would expect from a simple examination of the samples. Had we picked out the shrunken kernels from the sample grown with nitrogen, or even sifted out the small kernels, and compared kernels of equal size we, undoubtedly, would have had a very different result. Such a procedure was, of course, not to be thought of; it would, however, have given us results for kernels more nearly normal and equal in size. How significant this factor is, may be inferred from the fact that the crushing strength of the individual kernels in the case of the nitrate sample varies from 5,000 to 17,000 grams. The difference in the size of the kernels is indicated by the weight for 1,000 kernels. The wheat grown with nitrate weighed 31.5 grams and that grown with potassium weighed 38.77, a difference of 23.0 percent. There was more difference than is suggested by these weights, for the wheat grown with the application of nitrogen is shrunken while that grown under other conditions is full and round;

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this difference in form must certainly make a big difference in the crushing strength of the kernels, in whatever position they may be placed under the pestle. We placed every kernel in the same position, namely, crease downward. I do not think that there is any result obtainable by this method of investigation which is definite enough to advance the object of our investigation.

THE WHEATS GROWN AND CULTURAL METHODS USED

In the experiments planned to ascertain something definite concerning the part played by individual factors in determining the character of our wheat we have used three varieties. Defiance, a wheat of local origin, which has retained public favor in this State, for upwards of thirty years, Red Fife and Kubanka. I chose spring-wheat, because, until recently, almost no winter-wheat was grown in the State, further, because, its whole growing period, from planting till maturity, is short and without any resting period, or one principally of underground development, and also because we escape the danger of winter-killing. We grew twelve plots of each variety, three plots were dressed with sodic nitrate, three with rock superphosphate, three with potassic chlorid and three were used as check plots. This gives us 36 plots in all. The experiments with the different varieties were the same, so that the statement of them for one variety will suffice for the others.

In 1913, Sections 1700 and 1800 were plowed with a turning plow to a depth of 12 inches and with a subsoil plow to a depth of 16 inches, or 4 inches deeper than the turning plow. Section 1900 was turned to a depth of nine inches and not subsoiled. The deep cultivation was given, because the average depth to which it had previously been stirred was not more than 6 or 7 inches. The deep stirring was in some respects a mistake, but this has been discussed elsewhere and as no very serious results followed, it need not be discussed at this time. The fertilizers were applied as follows: Nitrogen at the rate of 120 pounds per acre to the plots receiving this fertilizer in Section 1700, 80 pounds to those in Section 1800 and 40 pounds to those in Section 1900. Phosphorus, at the rate of 60 pounds of soluble phosphorus to the acre, to the plots receiving this manure in Section 1700, 40 pounds to those in Section 1800, and 20 pounds to those in Section 1900. Potassium at the rate of 200 pounds per acre to those plots receiving it in Section 1700, 150 pounds per acre to those in Section 1800, and 100 pounds to those in Section 1900. There was a check plot in each section of land for each variety. It will be noticed that the plots in Section 1900 received the minimum amount. We have adhered to this order throughout the three seasons. The whole amount of phosphorus and potassium was applied at the time of planting and was harrowed in.

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An application of 40 pounds of nitrogen was made to all of the plots that were treated to this manure at planting time and harrowed in just as the other fertilizers. But the plots receiving larger quantities received subsequent applications; those plots in Section 1800 another application of 40 pounds, and those in Section 1700 two other applications of this amount, 120 pounds in all. The applications of nitrogen, as sodic nitrate, were made at intervals of about four weeks. All plots received an irrigation 12-16 June and four plots received a second irrigation four weeks later, 11-13 July, in 1913 and 1914, but not in 1915, because the frequent light rains of this season kept the plants loaded with water. The characteristics of the weather, especially for 1913 and 1915, have been stated, as also have the general crop-data, yield per acre, weight per bushel, and the ratio of straw to grains. An examination of the figures giving this latter ratio will show that it is very abnormally high for the Defiance in 1914, and for all varieties in 1915. There were two causes operative in 1915 tending to bring this about. One of these causes was the presence of an unusually large amount of wild oats which increased the weight of the straw and for which no adequate compensation was made in the weight of the grain. This cause had nothing to do with this ratio for the Defiance in 1914.

RUST INCREASED RATIO OF STRAW TO GRAIN

While the following statements may not belong in this place, their misplacement may emphasize the explanation offered for the appearance of the wild oats, namely, that we distributed them over the land with the water that was applied the preceding autumn preparatory to cultivating it. This water simply washed out the ditches in which these wild oats had collected and distributed them on our land. The other cause alluded to, acted in a more direct and effective manner in increasing the ratio of straw to grain. This cause was the rust that developed on the plants. This parasite practically killed the Defiance wheat grown with the application of nitrogen in both 1914 and 1915. The grain produced in these plots could scarcely be called grain at all, and such as we got weighed as low as 52 pounds per bushel in 1914, and 47 pounds in 1915. The yield being low—it fell to less than 9 bushels in 1915—and the weight light, the ratio of straw to grain must necessarily be high. That this was wholly due to rust in 1914, and almost wholly so in 1915, there can be no doubt. The wild oats may be mixed with the wheat and increase the weight of the straw, but do not cause shrunken, light-weight grains, which is a characteristic effect of rust.

I have tried to show that we have but little justification in thinking that we can arrive at any certainty in regard to the real character-

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istics of our wheats by a study of general samples, because we have in them too great a variety of properties, and the effects of too many conditions, in part or wholly unknown to us. The big features of the climatic conditions have been asserted, but are not so well known that we can state exactly in what these consist. The influence of the soil-factors has been recognized in a general way, but has been considered small in comparison with climatic influences. Here again, neither the kind of effects, nor their extent have been made out. It may be, and probably is the fact, that the wheat plant is very susceptible to very slight changes in the balance of its nutritive solutions, and at the same time very sensitive, especially at certain periods in its development, to unfavorable climatic influences. Further, it is evidently very sensitive to the injury inflicted by some parasites, rust for instance. There may be differences in varieties in these respects, but there is no occasion for making modifications in these general statements, as they, in the main, seem to be correct.

COMPOSITION OF WHEATS GROWN IN 1913

The following tables present the composition of the wheats grown on our plots during the season of 1913, given by section and variety:

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WHEATS GROWN ON EXPERIMENTAL PLOTS IN 1913—SECTION 1700

Variety	Fertilizer per Acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance,	Nitrogen 120 lbs.....	11.825	1.921	1.598	2.362	2.630	14.989	59.788	1.142	35.37	13.98	10.340	0.442	0.440	33.50
Defiance,	Phosphorus 60 lbs.....	11.393	1.917	1.728	2.625	2.113	12.042	61.632	1.282	25.66	10.27	7.336	0.447	0.444	37.54
Defiance,	Potassium 200 lbs.....	11.493	1.930	1.725	2.505	2.012	11.469	61.236	1.255	23.40	9.53	6.736	0.447	0.425	38.19
Defiance,	None	11.455	1.943	1.605	2.603	2.016	11.492	62.154	1.249	24.33	9.99	7.067	0.452	0.436	37.03
Red Fife,	Nitrogen 120 lbs.....	10.408	1.823	1.815	2.630	2.665	15.188	60.192	1.249	36.07	13.83	10.200	0.452	0.488	30.81
Red Fife,	Phosphorus 60 lbs.....	10.390	2.006	1.775	2.642	2.358	13.442	61.308	1.501	26.87	10.92	7.848	0.476	0.502	33.56
Red Fife,	Potassium 200 lbs.....	10.303	1.994	1.808	3.000	2.274	12.961	62.910	1.467	23.40	11.23	8.151	0.475	0.442	33.53
Red Fife,	None	10.910	2.053	1.778	2.708	2.270	12.936	62.338	1.289	27.10	11.06	7.990	0.449	0.453	33.75
Kubanka,	Nitrogen 120 lbs.....	11.410	1.869	2.078	2.382	2.528	14.411	59.310	1.697	32.93	13.49	9.857	0.404	0.482	43.11
Kubanka,	Phosphorus 60 lbs.....	10.783	1.929	2.098	2.740	2.159	12.305	61.504	1.415	26.73	11.16	7.777	0.441	0.497	42.19
Kubanka,	Potassium 200 lbs.....	10.505	1.988	1.843	2.400	2.160	12.311	62.028	1.467	26.47	11.34	7.761	0.431	0.473	42.72
Kubanka,	None	10.288	1.981	1.998	2.455	2.144	12.221	59.670	1.352	27.33	11.29	8.201	0.441	0.445	42.13

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS IN 1913 —SECTION 1700

Variety	Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance,	Nitrogen, 120 lbs..	0.0699	0.2168	1.1789	1.1628	2.6297
Defiance,	Phosphorus, 60 lbs.	0.0418	0.1958	0.8756	0.9994	2.1126
Defiance,	Potassium, 200 lbs.	0.0523	0.1818	0.8238	0.9542	2.0121
Defiance,	None	0.0523	0.1958	0.8558	0.9022	2.0161
Red Fife,	Nitrogen, 120 lbs..	0.1049	0.2237	0.9855	1.3504	2.6645
Red Fife	Phosphorus, 60 lbs.	0.1328	0.2098	0.8830	1.1327	2.3583
Red Fife,	Potassium, 200 lbs.	0.1363	0.1958	0.7864	1.1554	2.2739
Red Fife,	None	0.1188	0.1678	0.8132	1.1697	2.2695
Kubanka,	Nitrogen, 120 lbs..	0.0804	0.1958	0.8755	1.3766	2.5283
Kubanka,	Phosphorus, 60 lbs.	0.0628	0.2517	0.9624	0.8818	2.1587
Kubanka,	Potassium, 200 lbs.	0.0663	0.1958	0.8704	1.0271	2.1599
Kubanka,	None	0.0593	0.1958	1.0498	0.8392	2.1441

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WHEATS GROWN ON EXPERIMENTAL PLOTS IN 1913—SECTION 1800

Variety	Fertilizer per Acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance,	Nitrogen 80 lbs.....	10.818	1.848	1.728	3.007	2.435	13.788	60.264	1.051	31.38	12.32	9.220	0.393	0.446	32.73
Defiance,	Phosphorus 40 lbs....	10.665	1.903	1.700	2.782	2.107	12.008	62.118	1.135	24.50	9.85	7.038	0.442	0.437	38.76
Defiance,	Potassium 150 lbs....	10.675	1.860	1.705	2.738	2.163	12.330	63.014	1.455	24.50	10.08	7.099	0.408	0.420	39.94
Defiance,	None	11.268	1.695	1.780	2.568	2.130	12.139	61.830	1.352	25.07	10.22	7.313	0.416	0.453	38.84
Red Fife,	Nitrogen 80 lbs.....	9.828	1.928	1.810	2.684	2.616	14.909	60.002	1.329	32.20	12.84	9.487	0.405	0.466	34.36
Red Fife,	Phosphorus 40 lbs.....	9.810	2.085	1.783	2.525	2.323	13.242	61.340	1.091	27.00	11.04	8.171	0.458	0.440	34.59
Red Fife,	Potassium 150 lbs....	10.095	2.013	1.918	2.582	2.422	13.806	61.760	1.221	27.20	11.07	8.039	0.459	0.423	35.94
Red Fife,	None	10.633	2.050	1.865	2.755	2.531	14.428	61.382	1.147	28.83	11.55	8.335	0.462	0.410	35.34
Kubanka,	Nitrogen 80 lbs.....	11.780	1.721	1.995	2.830	2.414	13.758	60.894	1.449	30.10	12.30	8.530	0.373	0.423	42.18
Kubanka,	Phosphorus 40 lbs...	11.215	1.877	1.935	2.412	2.090	11.911	61.578	1.519	26.50	11.06	7.815	0.407	0.477	43.56
Kubanka,	Potassium 150 lbs....	11.110	1.875	1.935	2.462	2.111	12.032	62.622	1.392	25.50	10.60	7.316	0.411	0.434	43.76
Kubanka,	None	11.330	1.971	1.800	2.862	2.114	12.048	63.374	1.438	25.33	10.63	7.572	0.423	0.480	45.96

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS 1913—SECTION 1800

Variety	Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance,	Nitrogen, 80 lbs...	0.0699	0.1748	1.0764	1.1134	2.4345
Defiance,	Phosphorus, 40 lbs.	0.0638	0.1888	0.8506	1.0045	2.1067
Defiance,	Potassium, 150 lbs.	0.0558	0.1818	0.8716	1.0539	2.1631
Defiance,	None	0.0523	0.1678	0.8704	1.0392	2.1297
Red Fife,	Nitrogen, 80 lbs...	0.1049	0.2028	0.9855	1.3224	2.6156
Red Fife,	Phosphorus, 40 lbs.	0.0979	0.2028	0.8900	1.1324	2.3231
Red Fife,	Potassium, 150 lbs.	0.1014	0.2307	0.8771	1.2129	2.4221
Red Fife,	None	0.0944	0.2377	0.8982	1.3009	2.5312
Kubanka,	Nitrogen, 80 lbs...	0.0628	0.2168	0.9298	1.2043	2.4137
Kubanka,	Phosphorus, 40 lbs.	0.0523	0.2168	0.9356	0.8849	2.0896
Kubanka,	Potassium, 150 lbs.	0.0488	0.2237	0.7947	1.0437	2.1109
Kubanka,	None	0.0523	0.2237	0.8191	1.0186	2.1137

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WHEATS GROWN WITH FERTILIZERS IN 1913—SECTION 1900

Variety	Fertilizer per Acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance,	Nitrogen 40 lbs.....	11.762	1.851	1.728	2.532	2.290	13.051	63.486	1.306	24.33	10.13	7.241	0.454	0.476	35.01
Defiance,	Phosphorus 20 lbs....	11.830	1.792	1.820	2.600	1.865	10.631	64.010	1.392	20.17	8.53	5.854	0.456	0.473	35.23
Defiance,	Potassium 100 lbs....	11.565	1.894	1.798	2.528	1.960	11.173	63.400	1.215	23.00	9.57	6.412	0.480	0.476	33.74
Defiance.	None	11.798	1.905	1.775	2.575	2.038	11.615	63.224	1.063	23.50	9.59	6.914	0.480	0.480	36.37
Red Fife,	Nitrogen 40 lbs.....	10.363	1.961	1.803	2.512	2.543	14.493	61.956	1.438	30.07	12.26	8.709	0.479	0.501	33.82
Red Fife,	Phosphorus 20 lbs....	10.653	2.065	1.860	2.600	2.394	13.646	62.334	1.478	28.40	11.67	8.305	0.522	0.496	34.18
Red Fife,	Potassium 100 lbs....	10.278	2.077	1.878	2.617	2.487	14.178	61.812	1.323	27.66	11.16	8.174	0.505	0.444	34.20
Red Fife,	None	10.378	2.060	1.750	2.675	2.470	14.079	63.290	1.352	28.57	11.58	8.305	0.506	0.454	34.22
Kubanka,	Nitrogen 40 lbs.....	11.515	1.822	1.878	2.437	2.261	12.887	61.272	1.656	28.80	11.82	8.407	0.419	0.461	46.82
Kubanka,	Phosphorus 20 lbs....	11.248	1.974	1.960	2.562	2.187	12.464	63.090	1.549	26.66	10.92	7.803	0.444	0.471	46.53
Kubanka,	Potassium 100 lbs....	10.850	1.889	1.748	2.600	2.253	12.843	61.729	1.341	25.57	10.80	7.781	0.432	0.497	45.33
Kubanka,	None	11.200	1.947	1.813	2.522	2.207	12.583	62.046	1.467	25.40	10.79	7.661	0.458	0.494	45.53

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS 1913—SECTION 1900

Variety	Fertilizer per acre	Amid Nitrogen Precent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance,	Nitrogen, 40 lbs...	0.0488	0.1958	0.8599	1.1852	2.2897
Defiance,	Phosphorus, 20 lbs.	0.0453	0.1958	0.7143	0.9097	1.8651
Defiance,	Potassium, 100 lbs.	0.0384	0.2098	0.7631	0.9601	1.9601
Defiance,	None	0.0483	0.2028	0.8417	0.9449	2.0377
Red Fife,	Nitrogen, 40 lbs...	0.0909	0.2098	0.9436	1.2983	2.5426
Red Fife,	Phosphorus, 20 lbs.	0.0909	0.2517	0.8923	1.1591	2.3940
Red Fife,	Potassium, 100 lbs.	0.0909	0.2866	0.9203	1.1895	2.4873
Red Fife,	None	0.0593	0.3006	0.9472	1.1629	2.4700
Kubanka,	Nitrogen, 40 lbs...	0.0349	0.2726	0.8738	1.0796	2.2609
Kubanka,	Phosphorus, 20 lbs.	0.0349	0.2447	0.8459	1.0611	2.1866
Kubanka,	Potassium, 100 lbs.	0.0628	0.2098	0.7527	1.2279	2.2532
Kubanka,	None	0.0418	0.2377	0.8110	1.1171	2.2076

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MINERAL CONSTITUENTS OF WHEAT GROWN AT FORT COLLINS, CROP OF 1913

Variety	Fertilizer per Acre	Sp. Gr.	SiO_2 Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	Total P Percent	Inorganic P Percent	Organic P Percent	Total N Percent
Defiance	Nitrogen 80 lbs..	1.4228	0.011	0.004	present	0.043	0.132	0.419	0.023	0.058	0.153	0.393	0.026	0.367	2.435
Defiance	Phosphorus 40 lbs.....	1.4311	0.016	0.004	present	0.036	0.146	0.408	0.036	0.052	0.120	0.442	0.029	0.413	2.107
Defiance	Potassium 150 lbs.....	1.4355	0.015	0.006	present	0.030	0.136	0.401	0.041	0.058	0.128	0.408	0.023	0.385	2.162
Defiance	None	1.4347	0.030	0.005	present	0.037	0.141	0.391	0.037	0.060	0.116	0.416	0.029	0.387	2.119
Red Fife	Nitrogen 80 lbs.....	1.4405	0.044	0.005	present	0.033	0.150	0.438	0.027	0.072	0.120	0.414	0.022	0.392	2.615
Red Fife	Phosphorus 40 lbs.....	1.4429	0.013	0.007	present	0.033	0.155	0.439	0.022	0.063	0.115	0.456	0.030	0.426	2.323
Red Fife	Potassium 150 lbs.....	1.4468	0.009	0.007	present	0.027	0.152	0.430	0.019	0.093	0.114	0.457	0.026	0.431	2.422
Red Fife	None	1.4401	0.017	0.006	present	0.038	0.153	0.444	0.010	0.135	0.113	0.461	0.029	0.432	2.521
Kubanka	Nitrogen 80 lbs.....	1.4400	0.031	0.005	present	0.048	0.133	0.453	0.002	0.117	0.124	0.364	0.014	0.350	2.442
Kubanka	Phosphorus 40 lbs.	1.4354	0.034	0.005	present	0.041	0.141	0.453	0.016	0.134	0.101	0.407	0.016	0.391	2.085
Kubanka	Potassium 150 lbs.....	1.4368	0.010	0.004	present	0.035	0.122	0.458	0.011	0.129	0.104	0.411	0.017	0.394	2.111
Kubanka	None	1.4355	0.030	0.005	present	0.031	0.137	0.454	0.010	0.130	0.093	0.423	0.016	0.407	2.114

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SEASON OF 1913 VERY FAVORABLE—WHAT OUR EXPERIMENTS SHOWED US

The season of 1913 was very favorable throughout the whole period of growth and ripening. The early spring was quite wet and our planting was late. The period from planting till harvest was 101 days. There was very little rust, so little that we shall consider its effects negligible. A comparison of the nitrogen found in the three samples of each variety grown on the check plots shows that there is a greater variation in them than can be attributed to errors in the determinations; further, that, corresponding to the differences in the check plots, the samples of Defiance and Red Fife are higher on Section 1800 than on the other two sections. In the case of the Kubanka, there is but little difference, especially in samples grown without the application of nitrogen. It shows, further, that there is an increase of nitrogen in those samples grown with the application of this element over that found in the check plots for each variety of wheat and in each section. This increase equals from one to six-tenths of one percent. This difference is consistent, too, throughout the statement for the wet, dry and true-gluten. It has frequently been shown that the nitrogen content of wheat can be increased by the application of sodic nitrate and also by ammoniacal salts. This statement is also made in regard to other nitrogenous manures, sheep manure for instance. This statement, according to our observation, needs the following modification: Provided the nitrogen is converted into nitric-nitrogen with sufficient rapidity. We have used only one form of nitrogen in our experiments at Fort Collins, sodic nitrate, but we have one set of samples grown with farmyard manure, which gives different results. Our samples grown with the application of nitrogen, in the form of sodic nitrate, regularly show an increase in the nitrogen content of the crops. Crops grown with farmyard manure, show a decided advantage in yield, both of straw and grain, but only a very small increase in the nitrogen content. The maximum difference in any one of the three pairs of samples was 0.20 percent nitrogen; the other two pairs show a difference of 0.01 and 0.05 percent respectively. The greatest difference, 0.20 of one percent, may be due to other causes than the manure, but as the record stands, this difference would be attributed to its effects. These samples were obtained for another purpose and will be given in connection with the subject that they are more specifically intended to illustrate. I have not used ammoniacal salts on any plots, and can only state, on the authority of others, that their effects are the same as those of nitrogen in the form of sodic nitrate.

Two other questions present themselves for consideration in this connection, namely, are there any effects produced by the other plant

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foods which we can recognize as specifically due to them, and are our analytical results accurate enough to justify us in assuming that the differences found are well enough established to be taken as the basis of inferences in regard to these effects? We should extend these questions to include regularity in the direction of these differences, not only for the samples of the different varieties for one year, but in these same varieties for several years.

I am very firmly convinced that minute differences as expressed in percentage composition correspond to very significant differences in the properties of the wheat, provided that we can be certain that the percentages obtained are correct within limits, as narrow as or narrower than those with which the properties of the grain actually vary. I fear that it is so difficult to attain to this degree of certainty in regard to our analytical results, that these questions in regard to the specific effects of fertilizers and the manner in which they modify one another must remain in some doubt.

The analyses given in the preceding tables are all based on the air-dried grain. The moisture in our samples is quite constant for the individual varieties grown on the same section of land. There is but one instance in nine groups of four samples each in which we find a difference as great as or greater than 1 percent, so that the differences in the percntage, of potassium, for instance, due to this variation will fall in the third decimal place and will be less than five. The ash constituents in the wheat were determined by one analyst, and the phosphorus and potassium in the general analyses of wheat by another. The methods used in the case of the phosphorus were the same, but they used different methods in determining the potassium. The difference in the percentages of the potassium due to this cause is from two to three one-hundredths of 1 percent. A comparison of the results obtained will show but one or two serious discrepancies. On the other hand, we find such agreement in the big features of the results that we can accept them as established on a pretty firm basis.

There are reasons why we should prefer not too accept the results of the 1913 crop as indicative of the effects of the soil factors upon the composition of the wheat. One reason is that the land had been in other crops during the preceding years and we do not know with as much certainty as we should the conditions preceding the growing of this crop. On the other hand, this crop grew and matured under favorable weather conditions, and probably gives us the most representative samples of our average wheat that we have obtained, but it is doubtful whether it gives us the best illustration of the influence of the soil factors upon the composition of the wheat.

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EFFECTS OF FERTILIZERS ON THE THICKNESS OF THE BRAN

It is usual to take the nitrogen content as the principal criterion in judging the differences in wheat. The other constituents usually given in an analysis, moisture, ash, fat, fiber, and even starch, are of much less importance. The crude fiber as determined in the wheat corresponds roughly to the epidermal portions of the wheat, and in a rough way indicates the relative thickness of these parts. It might be interesting from an anatomical standpoint, to know whether the fertilizers influence these protective features of the grain or not, and how, but for our purposes these points are not of much interest and the results of the 36 analyses of wheat grown on our own plots, presented in the preceding tables, indicate no decisive and constant difference. The range of these determinations in the 36 samples is from 2.400 to 3.007 percent, or a maximum variation of 0.607 percent. The average percentage of crude fiber in the samples grown with application of nitrogen is, taken literally, the least of the four averages and that of those grown with potassium, the highest. The difference is 0.12 percent, too small for consideration from our standpoint. The starch, owing to its large percentage, will reflect the variation in the protein, the substance present in the next largest quantity; these two substances present in wheat in the largest quantities must bear an inverse relation to one another. There is nothing in our analyses to show that this is anything more than a numerical relation. If there be any other relation between these substances it is not shown by our results so far given. The formation of starch or carbohydrates, in general, may influence that of the protein or vice versa, but this is a physiological relation which our work does not present. The question of flinty and mealy kernels probably comes within the province of this relation. We have shown in Bulletin 205 that this is directly a question of the ratio between the nitrogen and potassium present in the soil and available to the plant. The ash in the analyses given was determined by the usual method of incineration, i.e., charring, extraction with water and subsequent ignition. There is no question but that some loss occurs in this method, but not enough to vitiate the results. The nine sets of samples agree in showing that those grown with the application of nitrates are a little lower than the others. This will be found to be the rule, but it is not altogether without exception. It is owing to difficulties in preparing the ash of grain and also of the straw that I have used the form "ash-constituents" in stating the analytical results of such determinations for both wheat-straw and grain. Leavitt and Le Clerc* have shown that there may be a very considerable loss of phosphorus in direct calcination. They found the difference between incineration at low redness and "redness" to equal 46.0 percent of the

* Journal Am. Chem. Soc., Vol. 30, pp. 391-394.

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phosphoric acid, that between incineration at "redness" and the acetate method to be equal to 35.0 percent of the P_2O_5. Without any knowledge of the results obtained by these authors, I found that it is practically impossible to obtain correct results in making this determination by igniting at a very low temperature, in a partially covered crucible over a very low Bunsen flame. I made a series of 38 determinations by ignition, and by dissolving in concentrated nitric acid with the addition of a sufficient quantity of magnesic oxide and subsequent ignition, and found the differences ranging from 10.0 to 37.0 percent of the phosphorus present. The determination of phosphorus in straw by ignition is still more difficult, owing to the excess of silica and carbon which, at a comparatively low temperature, may cause the volatilization of practically the whole of the phosphorus.

Leavitt and LeClerc think that the loss of phosphorus in making the determination of total ash in grain may be neglected.* According to our observations, the method of charring and extracting with water is unsatisfactory, especially if we are to consider differences of one or two tenths, or even hundredths of 1 percent, as significant of the effects of fertilizers or weather conditions. The results given in the preceding tables were obtained by this method, and we justify the use of these results on the supposition that, the method having been worked in a uniform manner, the results have an error, but this is common to all of them and in the same direction. The ash, or mineral-constituents, given in the table under the latter caption, were not determined by preparing an ash by the usual incineration. The air-dried wheat was dissolved in concentrated nitric acid and subsequently ignited, but this is not the place for these technical details.

The standards adopted for reference are averages given by Leach in his work on "Food Inspection and Analysis". Reference will also be made to Hungarian wheats given by Kosutany.

* Loc. Cit.

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AVERAGE COMPOSITION OF WHOLE WHEAT*

	Domestic	Foreign
Weight of 100 kernels	3.866 grams	4.076 grams
	Percent	Percent
Moisture	10.62	11.47
Protein	12.23 (11.16 Nx5.7)	12.08 (11.02 Nx5.7)
Fat	1.77	1.78
Fiber	2.36	2.28
Ash	1.82	1.73
Carbohydrate (Diff)	71.18 (72.27)	70.66 (71.72)
Wet Gluten	26.46	25.36
Dry Gluten	10.31	9.82

Leach gives a somewhat fuller analysis of wheat, taken from a tabulation of the composition of the principal cereal grains by Villier and Collint.

Water	13.65	
Protein	12.35	(11.25 Nx5.7)
Fat	1.75	
Sugar	1.45	
Gum and Dextrin	2.38	
Starch	64.08	
Cellulose	2.53	
Ash	1.81	

THE COMPOSITION OF HUNGARIAN WHEAT

The following table giving the data pertaining to the composition of Hungarian wheat is of interest, if for no other reason, because of the universally high reputation of Hungarian flour. I have preferred to give Kosutany's data for each of the six seasons rather than to average them, for this would obscure, or entirely conceal, the seasonal differences.

*Leach "Food Inspection and Analysis," p. 272.
†Leach "Food Inspection and Analysis," p. 271.

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MINIMUM, MAXIMUM AND AVERAGE COMPOSITION OF HUNGARIAN WHEAT*

Harvest	Weight per 1000	Mealiness	Moisture	Ash	Fat	Fiber	Nitrogen	Protein		N-free	Wet Gluten	Dry Gluten
Minimum	24.67	20.44	10.95	1.129	1.709	1.129	1.733	10.836		64.824	15.00	5.75
Maximum	41.72	75.10	14.40	1.958	2.309	1.958	2.731	17.074		70.811	34.45	11.95
Average 50/50.....	31.424	41.857	12.612	1.735	2.056	1.735	2.106	13.162	(12.004)† (Nx5.7)	67.915	21.70	7.962
Minimum	23.11	4.50	11.602	1.38	1.673	1.860	1.846	11.534		61.34	17.00	6.85
Maximum	38.50	75.87	15.162	2.26	2.399	3.351	2.950	18.434		70.06	43.40	14.80
Average 57/57	29.38	24.56	13.545	1.73	2.051	2.471	2.298	14.366	(13.099) (Nx5.7)	65.78	26.77	9.87
Minimum	23.90	4.12	11.79	1.22	1.61	1.69	1.380	8.63		63.58	18.50	6.85
Maximum	40.24	77.87	16.86	1.96	2.30	2.43	2.600	16.25		71.77	50.75	15.30
Average 53/53.....	31.42	36.44	14.57	1.58	1.94	2.01	1.897	11.86	(10.83) (Nx5.7)	68.04	26.17	9.64
Minimum	27.60	6.24	9.99	1.40	1.41	2.02	1.667	10.42		67.40	23.95	7.32
Maximum	43.16	71.24	11.34	1.89	1.73	2.74	2.624	16.40		73.43	44.87	14.75
Average 53/53.....	34.39	33.71	10.82	1.66	1.54	2.36	1.991	12.44	(11.35) (Nx5.7)	71.17	30.30	10.21
Minimum	26.63	0.00	10.34	1.44	1.44	2.06	1.684	10.54		67.13	22.90	8.12
Maximum	42.88	62.00	11.40	1.91	1.84	2.72	2.803	17.52		72.94	52.00	15.90
Average 53/53.....	33.78	24.09	10.80	1.66	1.60	2.31	2.122	13.23	(12.20) (Nx5.7)	70.36	32.72	11.63
Minimum	27.53	0.00	10.03	1.41	1.34	2.01	1.750	10.94		61.94	24.55	8.33
Maximum	40.17	82.00	11.23	1.98	1.88	2.66	3.395	21.22		72.82	52.55	18.83
Average 53/53.....	36.62	26.08	10.91	1.73	1.61	2.30	2.319	14.37	(13.22) (Nx5.7)	69.09	37.33	12.11

*Kosutany, "Der ungarische Weizen und das ungarische Mehl"—pp. 102-108.
†I have added the product, Nx5.7, because we have used this factor, while Kosutany used 6.25.

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CHECK SAMPLES OF 1913 REPRESENT NORMAL COLORADO WHEAT

In my judgment we have no set or sets of samples which are more fairly representative of normal Colorado wheat than the check samples grown in 1913. We may include with these the samples grown with the application of potassium and also those grown with the application of phosphorus, but not those grown with the application of nitric nitrogen. My reasons for including the former, but not the latter samples, are that the former differ less from those grown on the check plots in their physical properties, than samples grown in the same district differ from one another, but which is not true of those grown with the application of nitrates. It is true that we find the same kind of differences, and as great, in the samples of wheat grown in different sections of the State, as we find in our samples grown under different conditions, but the marked exceptions of this character, which have fallen under my observation, have been due to an unusual supply of nitric-nitrogen formed in the soil. We would obtain a better average for our wheats by including the samples grown with the applications of nitric-nitrogen, but our object is to present the facts, as nearly as we may see them, and not to present a good average composition for our wheat.

In the following statement, the analysis given under each section is the average of wheat from three plots, a check plot, a plot with the addition of phosphorus and one with the addition of potassium. The average in each case is really the average of nine analyses. The varieties are given and no remarks are needed in this place.

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AVERAGE COMPOSITION OF WHEATS (IN PERCENT) GROWN WITHOUT THE APPLICATION OF NITROGEN IN 1913*

	Defiance				Red Fife				Kubanka				
	Sec. 1700	Sec. 1800	Sec. 1900	Avg.	Sec. 1700	Sec. 1800	Sec. 1900	Avg.	Sec. 1700	Sec. 1800	Sec. 1900	Avg.	General Avg
Moisture	11.447	10.836	11.731	11.338	10.534	10.179	10.403	10.372	10.525	11.218	11.099	11.047	10.919
Ash	1.927	1.819	1.931	1.893	2.024	2.049	2.067	2.047	1.966	1.908	1.937	1.937	1.959
Fat	1.686	1.728	1.798	1.771	1.787	1.755	1.829	1.790	1.979	1.890	1.840	1.903	1.821
Fiber	2.578	2.696	2.568	2.614	2.783	2.621	2.361	2.588	2.532	2.579	2.561	2.557	2.586
Nitrogen	2.047	2.133	1.955	2.045	2.301	2.425	2.450	2.392	2.154	2.105	2.216	2.158	2.178
Protein (Nx5.7)	11.668	12.159	11.140	11.656	13.103	13.825	13.968	13.632	12.279	11.997	12.630	12.302	12.530
Starch	61.674	62.321	63.578	62.558	62.185	61.661	62.479	62.108	61.067	62.526	62.288	61.961	62.209
Sucrose	1.245	1.311	1.223	1.256	1.419	1.153	1.384	1.319	1.411	1.450	1.452	1.438	1.338
Wet Gluten	24.450	24.690	22.220	23.790	27.460	27.680	28.210	27.780	26.840	25.780	25.870	26.160	25.910
Dry Gluten	9.930	10.050	9.230	9.770	11.070	11.220	11.470	11.250	11.260	10.760	10.840	10.950	10.680
True Gluten	7.045	7.150	6.394	6.863	7.996	8.182	8.261	8.146	7.913	7.567	7.748	7.743	7.584
Phosphorus	0.445	0.422	0.472	0.446	0.467	0.460	0.511	0.479	0.438	0.414	0.445	0.432	0.452
Potassium	0.435	0.437	0.476	0.449	0.466	0.424	0.465	0.452	0.472	0.463	0.487	0.473	0.458

* Each analysis in this table is an average of three analyses.

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THE EFFECT OF NITRATES ON NITROGEN CONTENT

That the nitrogen content of wheat may be increased by the application of sodic nitrate or ammonia salts, has been known a long time, so there is nothing new in the statement of the fact. The nitrates impart characteristic physical properties to wheat grown with their application. These properties are usually considered desirable if the nitrate is not added in too large quantities. The following analyses are given to show to what extent the chemical composition was affected, and also to show why we omitted them from the samples taken as representative of our wheats. The reason, for the present time at least, may be stated to be that they are quite different from the average of wheats grown without it. The statement of the analyses will show how different they are, and to what extent the composition of the wheat responds to the application of various amounts of this salt. The results in this respect increase with the amount applied, but the effect produced is not proportional to the amount, i.e., the minimum amount produces a certain result; three times this amount will not necessarily produce three times this effect, it may be more or less than three times. The same is true of the physical characteristics of the berries, the larger amounts showing a strong tendency to produce shrunken berries.

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AVERAGE COMPOSITION OF WHEATS (IN PERCENT) GROWN WITH APPLICATION OF NITROGEN—1913

	Defiance				Red Fife				Kubanka				
	Nitrogen Per Acre				Nitrogen Per Acre				Nitrogen Per Acre				
	120 lbs. Sec. 17.0	80 lbs. Sec. 1800	40 lbs. Sec. 1900	Avg.	120 lbs. Sec. 1700	80 lbs. Sec. 1800	40 lbs. Sec. 1900	Avg.	120 lbs Sec. 1700	80 lbs. Sec. 1800	40 lbs Sec. 1900	Avg.	General Avg.
Moisture	11.325	10.818	11.763	11.469	10.408	9.828	10.368	10.200	11.410	11.780	11.515	11.568	11.079
Ash	1.921	1.848	1.851	1.873	1.823	1.928	1.961	1.904	1.869	1.721	1.822	1.771	1.849
Fat	1.598	1.728	1.728	1.685	1.815	1.810	1.803	1.809	2.078	1.995	1.878	1.984	1.826
Fiber	2.362	3.007	2.532	2.634	2.630	2.684	2.512	2.609	2.382	2.830	2.437	2.550	2.598
Nitrogen	2.630	2.435	2.290	2.452	2.665	2.616	2.543	2.608	2.528	2.414	2.261	2.401	2.487
Protein (Nx5.7)	14.989	13.788	13.051	13.943	15.188	14.909	14.493	14.863	14.411	13.758	12.887	13.719	14.175
Starch	59.788	60.264	63.486	61.179	60.192	60.002	61.956	60.717	59.310	60.894	61.272	60.492	60.796
Sucrose	1.142	1.051	1.306	1.166	1.249	1.329	1.438	1.339	1.697	1.449	1.656	1.601	1.369
Wet Gluten	35.370	31.330	24.330	30.343	36.070	32.200	30.070	32.780	32.930	30.100	28.800	30.610	31.244
Dry Gluten	13.980	12.320	10.130	12.150	13.830	12.840	12.260	12.980	13.490	12.300	11.820	12.540	12.560
True Gluten	10.340	9.220	7.241	8.934	10.200	9.487	8.709	9.465	9.857	8.530	8.407	8.931	9.110
Phosphorus	0.442	0.393	0.454	0.423	0.452	0.405	0.479	0.445	0.404	0.373	0.419	0.399	0.422
Potassium	0.440	0.446	0.476	0.454	0.488	0.466	0.501	0.485	0.482	0.423	0.461	0.455	0.465
Weight per 1000		32.720				34.360				42.180			

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NITRATES CAUSE A DEPRESSION OF PHOSPHORUS

The physical characteristics of the berries produced by the application of nitrogen have already been mentioned. These kernels are relatively small, flinty, translucent, hard, and often shrunken. The marked feature of the composition is the increase in the nitrogen content; and with this, in the wet, dry, and true gluten. The differences between the phosphorus in the general averages given in the last two tables differ only a few hundredths of 1 percent, but a comparison of the phosphorus given in the other analyses shows that this element is regularly lower in the nitrate samples, than in the others. In other words, assuming that the check plots give us wheat of normal phosphorus content, the nitrates have caused a depression of this element.

NITRATE-FERTILIZED PLANTS MORE SUSCEPTIBLE TO RUST

In Bulletin 208, and again in Bulletin 217, it was shown that nitric-nitrogen produces marked effects upon the composition of the plant in that it increases all forms of nitrogen in the plant throughout the season; further, that it exercises a decided influence upon the mineral constituents of the plant; first in depressing the silicon, second in increasing the calcium, potassium and magnesium, but does not effect the phosphorus. Its effect upon the phosphorus in the grain is to depress it. This is quite evident in the table entitled "Mineral Constituents of Wheat, Crop of 1913". The difference in the general averages given in the two preceding tables is small, but this difference is persistent and, with few exceptions, plainly appears in individual analyses. The effect upon the amount of potassium is in the same direction in both plant and grain, namely to increase it, but this is less marked in the grain than in the plant. The whole character of the plant and its products, as well as its appearance, is, according to this, greatly affected by the supply of nitric-nitrogen in the soil. This conclusion is entirely in harmony with the deportment of the plant, which lodges easily, and when not lodged often shows marked abnormality in ripening, the middle portions of the plants and leaves remaining green, or at least very immature, while the top and bottom portions appear, and I think are, ripe. Further, I do not think that any doubt can be entertained that these plants are much more readily attacked by rust, than others of the same variety grown with other fertilizers or with none. There are differences which are known and really need no mention, such as the softness of the straw, a feature which is evident to persons handling it. There is a marked depression of silicon ranging from 14 to 29 percent of the total in the plant. I do not know how significant this difference may be, nor do I know that the weakness and softness of the straw is dependent upon this difference; I do not intend to attempt

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to give an explanation of these facts. It is, however, clear that both the plants and grain grown with the application of nitrates are different in chemical composition as well as in physical properties from those grown without them. These latter, and, in fact, the former also, are those ascribed to hard wheats, small, translucent, dark amber, flinty berries with high nitrogen content, at least, higher nitrogen content than wheat of the same variety grown under otherwise identical conditions, including both soil and climate.

COMPARISON OF STANDARDS ADOPTED AND RESULTS GIVEN

It may now not only be permissible, but advisable, to point out some of the relations between the standards adopted and the results given by our general samples, as well as with our wheats grown under more definitely known conditions.

I take it that the average given by Leach in his work includes both spring and winter-wheat, and some allowances should be made for this fact, though it does not appear from our general samples that there is any distinction to be made in regard to nitrogen content or degree of mealiness. Nevertheless, it is proper to remember that the wheats experimented with are all spring-wheats, though I do not believe that emphasis should be laid upon this fact. The weight per 1,000 kernels varies with the varieties. The average for the Defiance grown without nitrate is 39.18, for Red Fife 35.29 and for Kubanka 44.42 grams. Two of them are higher than the averages given for domestic wheats and one lower. The Red Fife is a small-kerneled wheat and the Kubanka, as it ordinarily grows with us, a large-berried one. In these counts all kernels were taken, and the wheat had not been screened after threshing. Carefully screened wheat should give a higher weight per thousand. The chief feature in the statement of the composition is the close agreement between the standards given and our averages, even the protein differs less from that given in the standards than some of our individual samples not grown with the application of nitrogen differ from one another. The standard for domestic wheats is 11.16 percent (N x 5.7), for foreign wheats 11.02 (N x 5.7); we obtain 12.53 percent. The starch is quoted from Villier and Collin as 64.08; we obtain 62.20 percent. The wet gluten is so dependent upon the manipulator that its value is but small; the dry gluten is a much better criterion and this we find given as 10.31 percent for domestic wheat, ours gives 10.68 percent. If we average the six crops of Hungarian wheat given by Kosutany, we obtain for protein 12.10 (N x 5.7) and for dry gluten 10.24; figures very close to those given by our Colorado wheats, 12.53 and 10.68 respectively. The Hungarian wheats do not average so high in their absolute weight as ours, 1,000 grains averaged for the six years 32.83 grams. One of these six years yielded grain apparently somewhat smaller in kernel than usual and was, perhaps, an abnormal

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one, still the maximum average is only a little above the maximum for our smallest grained variety, the Red Fife, i.e., 36.62 against 35.94.

The general samples of winter-wheat average 13.31 percent protein and 11.59 percent dry gluten, the general samples of spring-wheat average 13.32 percent protein and 11.74 percent of dry gluten. Each of these pairs of averages is higher than the corresponding data for our spring-wheats, but lower than for our samples grown with nitrates; 14.18 percent protein, 12.56 percent dry gluten. Objection has been offered in previous paragraphs to accepting general samples, because it is practically impossible to ascertain a correct statement of the conditions under which they were grown, and quite as difficult to learn the extent to which the samples are representative as the quality of the samples will depend upon the judgment of the sender. The averages given above for the general samples have but little value for these very reasons. The lowest percentage of protein found in the 1912 crop of winter-wheat, grown at Fort Collins, was 14.15, while Turkey Red, grown at La Jara, contained only 8.22 percent, and Red Chaff, grown at Eckert, contained 10.05 percent. These differences are indicated by the physical properties of the kernels, but this is not enough to make known the conditions under which the wheats were grown. These low-protein wheats are extreme cases of mealy wheats, whereas, our Fort Collins samples are fairly flinty wheats, though mixed. Could we but know the soil conditions under which the various samples were grown, these differences, in most cases, would be explicable, as I have pointed out in the case of three samples of Turkey Red, grown in the same section of country, from the same lot of seed, under the same climatic conditions, and also, it is safe to assume, of irrigation, which, as we have already stated, has but little influence, provided the plants have a sufficient supply of water at the critical period in their development. We shall come back to the question of the effect of irrigation, not to that of a critical period which is here refered to, perhaps, in too general a manner. I feel entirely justified in referring to such a period by the marked effects, which I have seen produced by a delay of a few days in the application of water, upon the development of the crop. Returning to the general samples, which include some dry-land wheats, it is proper to state that these are not, as is often, if not usually, considered richer in protein than the irrigated wheats. The few samples that we have analyzed would rather support the opposite view. The same is true of the physical properties, for we find samples of dry-land wheat badly affected by mealiness, which is equivalent to saying relatively low in protein.

COLORADO WHEAT EQUAL TO BEST IN CHEMICAL COMPOSITION

So far as chemical composition is concerned, the data given indicates that our average wheat, which shows a varying percentage of

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mealiness, is equal to the very best of wheats. Further, that the two extremes, small-grained flinty wheat, on the one hand, and mealy wheat on the other, differ materially from the average wheat which is a mixture of these two kinds, the former may be taken as carrying not far from 2 percent more protein and the latter 3 percent, or more, less than the average.

We have intentionaly chosen conditions which present the results obtained under favorable weather conditions to as great an extent as possible, allowing the effects of our fertilizers upon the physical and chemical characteristics of our wheats to come out in the fullest, possible light. These effects have been shown to be determinative of those physical properties designated as hard and soft, which is in agreement with the conclusions given in Bulletin 205. Further, that these physical properties correspond to very deep-going differences in the composition of the plants and kernels, but the effects upon the composition of the kernels are even more radical, so far as we are able to interpret the results, than upon that of the plant. This is particularly apparent in the effects of nitric-nitrogen upon the crop. While the effects of potassium are quite evident, they are not so striking as those of the nitrogen. The effects of these fertilizers or plant-foods are antagonistic, in that, one increases the nitrogen content while the other tends to depress it, regularly in the stems and leaves of the plants, and in the case of a sufficient predominance to produce yellow-berry, to depress it greatly in the kernels. The phosphorus showed no regular and consistent effect upon the amount of nitrogen and was, in general, surprisingly indifferent in its results.

One of the reasons assigned for taking the samples grown in 1913 as representative of the normal wheat crop in Colorado was that the weather conditions throughout the season were more nearly normal than those of 1914 and 1915.

In some respects the season of 1914 was as favorable, if not more so, than that of 1913. But there was one feature which seriously affected our results; this was a short period of wet weather near the end of July, just before the ripening period of the grain. At the very end of this period we had a shower of short duration, but very heavy. How this injury suffered by the crop is to be apportioned between the whole period and the closing feature of it, I do not know, nor do I know how much to attribute to the direct injury caused by the weather, and how much to the indirect injury caused by the development of rust. I think that a very large amount of the injury should be attributed to the latter.

TIME AND MANNER OF RAINFALL, RATHER THAN QUANTITY, IMPORTANT TO CROP

The experiments were conducted on the same land and were in all respects duplicates of those of 1913. This means that we had wheat

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after wheat on the check and other plots with the same fertilizers as were applied the season before. The land was irrigated after the crop of 1913 had been removed. The stubble was disced in and the land plowed a few weeks later. The promise of the crop of 1914 was most flattering up to the end of July, at which time, as stated above, untoward conditions intervened, the most serious of which was, probably, the rust, but this was undoubtedly the result of the weather conditions. The rainfall during the last 10 days of July, 1914, was 1.38 inches, of which 0.87 inches fell on the 30th in less than two hours. The mean temperature during this period was 69.3 degrees F. In 1913 we had in the last 11 days of July, 1.53 inches and a mean temperature of 62. Nearly the whole of this fell on the 22, 23, and 24th and was followed by bright, cool weather. The grain was not beaten down and did not rust. It is evident that the time and manner of the rainfall and the conditions following it, rather than the amount of water, are the factors which come into play, for the rain in 1913 exceeded that of 1914, but was not followed by any bad results, whereas, the rainfall of 1914, the greater part of which fell on 30 July, was quite disastrous to the Defiance and injured the other varieties. Rust developed freely, especially on the Defiance, which it very seriously damaged, in fact, ruined.

We have given the average composition of our samples for 1913, excluding those in which the nitrogen had been increased by the application of nitrates because we do not consider them truly representative. The average protein content (N x 5.7) was 12.53 percent and that of the plots receiving nitrogen was 14.18, a difference of 1.65 percent. The physical properties of these wheats, as well as their composition, are so different that their elimination from the average is not only justified, but necessitated as a matter of fairness.

We have not given the meteorological details of the season of 1914, but we have stated that they were favorable up to 30 July, and that the promise of an excellent yield of good grain was all that could be desired.

A point suggested in a preceding paragraph relative to the order of the crops, i.e., wheat after wheat without and also with fertilizers, may occur to the reader as important in regard to the effect of this fact upon the wheat, its growth and composition. I willingly acknowledge that this point is not covered by my data, and that we are dependent on observations upon the growth and development of the plants, together with the yields obtained to answer this. The growth and development of the plants up to 30 July was more vigorous than in 1913. The plants were large, the head long, and the kernels were already well filled out but still soft when the rain came.

The correlation table given in Bulletin 217, p. 22, gives data setting forth the size of plants, length of heads, etc., and, with the table

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of yields, the weight per bushel, and the ratio of straw to grain given in this bulletin, shows that the check plots, except in the case of the Defiance, gave materially higher yields in 1914 than in 1913, and the weight per bushel was very high. In 1913, the Defiance check plots yielded 41.4, 40.6, and 41.3 bushels per acre, average 41.1 bushels, weight per bushel 62.3 pounds; in 1914, the average yield was 31.1 bushels, weight per bushel 56.7 pounds; in 1915, yield 19.5 bushels, weight per bushel 49.6 pounds. The Red Fife check plots averaged in 1913, 33.2 bushels, weight per bushel 64.0 pounds, anl in 1914, 47.2 bushels, weight per bushel 63.7 pounds; in 1915, 32.6 bushels, weight per bushel 60.8 pounds. The Kubanka checks averaged in 1913, 34.2 bushels per acre, weight per bushel 63.2 pounds, in 1914 the same plots averaged 47.8 bushels per acre and the weight per bushel was 64.9 pounds; in 1915, 32.8 bushels and weight per bushel 62.3 pounds. The data given in the correlation table and the comparative yields and weights per bushel, given for the three seasons answer fully the questions arising in connection with the succession of crops and exhaustion of the soil. The plants were well developed, the yields good and the weight per bushel, except in the case of the Defiance, above the average in each of three years.

The total rainfall in July, 1913, was 2.63 inches and the mean temperature 66.8 degrees F.; in 1914 the rainfall was 1.68 inches and the mean temperature 68.3 degrees F.; and in 1915 the rainfall was 2.12 inches and the mean temperature 64.74 degrees F.

In 1913 and 1914, we had but little cloudy weather, while in 1915 it was prevalent. We had only 11 days in July, 1913, which are recorded as clear. The weather conditions in August were good, especially in 1913 and 1914, but were not quite so favorable in 1915. In 1913, we had no rain in August prior to harvest, in 1914 we had 0.29 inches and in 1915, 0.57 inch. This 0.57 inch of rain did not interfere with our harvest, and it is a question whether it made our conditions any worse than they were already. I am quite certain that it would have done us no harm had it not been preceded by bad conditions in July, for the grain would have been so mature by this time that practically no injury would have resulted. We can, I think, with entire justice, neglect the weather conditions in August, not that I wish to assert that the one-half inch of rainfall in early August might not have injured our crop, but, as will appear later, bad conditions in the latter part of July, with very good conditions in early August, will produce very bad results, so I feel justified in neglecting the August conditions. Two things, of course, are here assumed as the causes of the bad results, one is the unfavorable weather conditions already mentioned, and the other is the condition of development of the plant at this time. That this latter factor cannot be too strongly emphasized is evidenced by the effects of these bad conditions on the Defiance wheat, compared with

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the same upon the Red Fife. That there may be a difference in the ability of these two varieties to withstand unfavorable conditions is very probable, still it is a fact that the Fife matures several days earlier than the Defiance when sown on the same date, and by the end of July is usually quite mature. I have, in a preceding paragraph, given the results of the seasons on the comparative yields of our check plots and it will be noticed that the effects of the same conditions were much less upon the Red Fife than upon the Defiance, which fact I attribute largely to the stage of development of the plants at the time the weather conditions caused the injury to the crop.

In the statement for the rainfall for July of each season, it will be noticed that we had the heaviest rainfall in 1913 and the next heaviest rainfall in 1915. The former crop was excellent in quality, so far as weight per bushel and chemical composition are concerned; and the latter, as we shall later see, while good in yield and weight per bushel for the Red Fife and Kubanka, was of inferior chemical composition. In these cases, it was not the amount of water that fell during the month that produced the inferior wheat, for the larger amount of rainfall was followed by the better quality of wheat. The distribution of the rainfall in the two seasons was quite different. In 1913 practically the whole of the rain fell between the 18th and 23rd, and during the month we had but one wholly cloudy day. In 1915 we had very different conditions, the rainfall was distributed more evenly throughout the month, especially through the last few days of it, and there was much cloudy weather. We also had heavy dews. The difference in mean temperature during the month in the two seasons was comparatively small, 66.8 degrees F., in 1913 and 64.7 degrees F., in 1915, or a difference of 2.1 degrees F. This statement relative to the difference in mean temperature is, perhaps, not quite sufficient, for the character of the grain is determined, or may be, by a much shorter period than the 31 days composing the month; for this reason the mean temperature during the last 10 days of the month may be given; this was 62.4 in 1913, and 65.9 in 1915. This difference, though small, only 3.5 degrees, together with the continuous wet weather, with cloudiness and heavy dews, and with the vigorous growth of plants, favored an abundant development of rust. We had somewhat the same conditions in 1914 as in 1915 with the difference that in 1914 the rain came mostly in one violent shower, which beat the grain down so that it formed a thick mat of green plants through which the ventilation was considerably impeded, with the result that rust developed with special abundance on the Defiance, and quite abundantly on the other varieties. I have unfortunately, no means of conveying a definite idea of the comparative severity of these attacks. The composition of the crops for the two seasons is given in the following tables, which also give the sections of land, the fertilizers and the amounts used:

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WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1914

Variety	Section 1700 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	120 lbs. nitrogen	8.755	2.036	1.855	3.812	2.203	12.557	59.832	1.175	30.17	12.31	9.129	0.429	0.547	21.15
Defiance	60 lbs. phosphorus	9.220	1.675	1.938	3.391	1.578	8.995	63.900	1.125	18.50	7.87	5.529	0.410	0.466	27.19
Defiance	200 lbs. potassium	9.420	1.585	1.863	3.229	1.501	8.585	65.177	1.113	20.50	8.59	6.013	0.377	0.484	31.01
Defiance	None	8.555	1.880	1.775	3.480	1.547	8.816	66.330	1.136	18.23	7.66	5.435	0.404	0.442	26.97
Red Fife	120 lbs. nitrogen	9.488	1.690	1.878	3.020	2.099	11.964	63.216	1.218	29.80	12.61	8.908	0.409	0.415	32.50
Red Fife	60 lbs. phosphorus	9.058	1.884	1.890	2.891	1.668	9.508	65.340	1.332	23.13	9.67	6.848	0.420	0.413	33.88
Red Fife	200 lbs. potassium	9.250	1.772	1.915	2.845	1.780	10.143	63.576	1.335	24.57	10.21	7.087	0.420	0.412	35.69
Red Fife	None	9.385	1.938	1.920	3.017	1.661	9.468	64.602	1.260	22.40	9.31	6.637	0.398	0.425	33.85
Kubanka	120 lbs. nitrogen	9.130	1.704	1.925	2.995	2.106	12.001	61.002	1.341	33.17	13.57	9.386	0.352	0.455	38.15
Kubanka	60 lbs. phosphorus	9.375	1.922	1.995	2.995	1.713	9.764	65.567	1.341	25.00	10.57	7.266	0.391	0.452	41.18
Kubanka	200 lbs. potassium	9.858	1.762	1.888	2.932	1.842	10.499	64.494	1.409	26.17	11.02	7.632	0.386	0.461	44.20
Kubanka	None	8.535	1.752	2.018	3.002	1.842	10.499	64.728	1.467	26.97	11.38	8.048	0.394	0.440	42.68

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1914

Variety	Section 1700 Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 120 lbs.	0.0699	0.2517	1.0439*	0.8375	2.2030
Defiance	Phosphorus, 60 lbs.	0.0523	0.1888	0.5954	0.7415	1.5780
Defiance	Potassium, 200 lbs.	0.0453	0.1678	0.5977	0.6902	1.5010
Defiance	None	0.0453	0.2168	0.4952	0.7892	1.5465
Red Fife	Nitrogen, 120 lbs.	0.0734	0.2028	0.7467	1.0761	2.0990
Red Fife	Phosphorus, 60 lbs.	0.0488	0.1888	0.6736	0.6568	1.6680
Red Fife	Potassium, 200 lbs.	0.0488	0.1818	0.6736	0.8753	1.7795
Red Fife	None	0.0734	0.1678	0.4671	0.9427	1.6610
Kubanka	Nitrogen, 120 lbs.	0.0523	0.2307	0.9030	0.9195	2.1055
Kubanka	Phosphorus, 60 lbs.	0.0523	0.1888	0.7539	0.7180	1.7130
Kubanka	Potassium, 200 lbs.	0.0418	0.2028	0.7038	0.8936	1.8420
Kubanka	None	0.0488	0.2098	0.7858	0.7981	1.8420

*This was repeated with same results.

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WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1914

Variety	Section 1800 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	80 lbs. nitrogen.....	8.452	1.755	1.960	3.380	2.092	11.924	60.732	1.074	31.07	12.38	8.691	0.346	0.436	28.77
Defiance	40 lbs. phosphorus.....	8.933	1.825	1.925	3.265	1.644	9.367	64.206	1.081	19.37	8.14	5.687	0.393	0.431	27.05
Defiance	150 lbs potassium.....	9.060	1.760	1.838	3.279	1.578	8.995	64.566	1.068	21.07	8.82	5.815	0.375	0.412	30.04
Defiance	None	8.918	2.017	1.918	3.571	1.835	10.460	63.144	1.057	24.40	10.09	7.000	0.426	0.437	25.67
Red Fife	80 lbs. nitrogen.....	8.783	1.697	1.860	3.135	1.922	10.955	62.280	1.139	28.73	11.80	8.377	0.364	0.393	30.42
Red Fife	40 lbs. phosphorus.....	8.703	1.812	1.930	3.113	1.668	9.468	62.910	1.272	21.67	8.78	6.304	0.399	0.405	33.39
Red Fife	150 lbs. potassium.....	9.140	1.867	1.838	3.062	1.724	9.824	63.774	1.335	23.03	9.46	6.764	0.403	0.403	34.34
Red Fife	None	8.485	1.947	1.903	2.960	1.794	10.223	63.144	1.221	25.77	10.42	7.459	0.412	0.437	31.50
Kubanka	80 lbs. nitrogen.....	9.455	1.703	1.933	2.992	2.168	12.358	61.255	1.386	32.33	13.72	9.520	0.343	0.418	40.03
Kubanka	40 lbs. phosphorus.....10.043		1.903	2.115	3.221	1.714	9.767	65.214	1.455	24.73	10.57	7.316	0.397	0.436	42.19
Kubanka	150 lbs. potassium.....	9.613	1.712	1.875	2.970	1.925	10.972	64.206	1.461	27.33	11.62	7.665	0.366	0.451	42.78
Kubanka	None	9.640	1.692	1.945	3.013	1.751	9.981	62.586	1.392	26.30	10.96	7.440	0.385	0.442	43.72

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1914

Variety	Section 1800 Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 80 lbs.....	0.0453	0.2517	0.8774	0.9176	2.0920
Defiance	Phosphorus, 40 lbs..	0.0453	0.2028	0.5977	0.7877	1.6453
Defiance	Potassium, 150 lbs..	0.0453	0.2028	0.6071	0.7228	1.5780
Defiance	None	0.0553	0.1838	0.7084	0.8820	1.8350
Red Fife	Nitrogen, 80 lbs....	0.0523	0.1838	0.6654	1.0155	1.9220
Red Fife	Phosphorus, 40 lbs..	0.0453	0.1678	0.6164	0.7383	1.6680
Red Fife	Potassium, 150 lbs..	0.0453	0.1748	0.6527	0.8507	1.7235
Red Fife	None	0.0488	0.1818	0.7015	0.8614	1.7935
Kubanka	Nitrogen, 80 lbs....	0.0488	0.2307	0.9162	0.9727	2.1680
Kubanka	Phosphorus, 40 lbs..	0.0488	0.1888	0.7061	0.7698	1.7135
Kubanka	Potassium, 150 lbs..	0.0663	0.2028	0.7445	0.9114	1.9250
Kubanka	None	0.0413	0.2168	0.7318	0.7706	1.7510

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WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1914

Variety	Section 1900 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	40 lbs. nitrogen	8.650	1.630	2.045	3.473	1.842	10.499	62.568	1.040	26.87	10.96	7.464	0.355	0.421	24.47
Defiance	20 lbs. phosphorus	8.730	1.849	1.998	3.282	1.586	9.015	64.818	1.099	20.00	8.24	5.861	0.392	0.446	26.05
Defiance	100 lbs. potassium	8.950	1.617	1.905	3.125	1.550	8.835	63.648	1.074	20.73	8.61	5.800	0.362	0.419	29.48
Defiance	None	8.855	1.845	1.895	3.273	1.557	8.875	63.216	1.181	25.83	10.54	7.254	0.415	0.443	25.41
Red Fife	40 lbs. nitrogen	8.903	1.605	1.825	3.937	1.953	11.132	63.180	1.161	29.57	12.01	8.336	0.370	0.414	30.64
Red Fife	20 lbs. phosphorus	8.973	1.807	1.863	2.915	1.647	9.388	64.917	1.260	22.00	8.94	6.433	0.399	0.430	33.70
Red Fife	100 lbs. potassium	9.140	1.865	1.868	3.152	1.751	9.981	63.414	1.289	26.50	10.72	7.486	0.411	0.415	35.60
Red Fife	None	8.925	1.861	1.870	3.051	1.821	10.380	64.044	1.147	27.50	10.80	7.528	0.421	0.451	32.37
Kubanka	40 lbs. nitrogen	9.485	1.614	1.835	2.950	1.960	11.172	63.540	1.472	30.30	12.52	8.212	0.351	0.558	40.27
Kubanka	20 lbs. phosphorus	8.673	1.677	2.048	2.907	1.786	10.273	63.190	1.438	27.40	11.66	7.929	0.380	0.572	42.84
Kubanka	100 lbs. potassium	8.753	1.587	1.985	2.980	1.866	10.636	63.792	1.553	28.13	11.81	7.915	0.391	0.555	42.18
Kubanka	None	10.053	1.862	2.190	2.962	1.731	9.867	64.917	1.488	27.07	12.19	8.111	0.416	0.582	40.97

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1914

Variety	Section 1900 Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 40 lbs.	0.0628	0.2098	0.6921	0.8773	1.8426
Defiance	Phosphorus, 20 lbs.	0.0453	0.1888	0.5931	0.7543	1.5815
Defiance	Potassium, 100 lbs.	0.0523	0.1958	0.5695	0.7324	1.5500
Defiance	None	0.0593	0.2098	0.7329	0.5550	1.5570
Red Fife	Nitrogen, 40 lbs.	0.0593	0.1888	0.7981	0.9068	1.9530
Red Fife	Phosphorus, 20 lbs.	0.0384	0.1678	0.7212	0.7196	1.6470
Red Fife	Potassium, 100 lbs.	0.0523	0.1888	0.6794	0.8305	1.7510
Red Fife	None	0.0488	0.1748	0.7154	0.8820	1.8210
Kubanka	Nitrogen, 40 lbs.	0.0418	0.2237	0.8156	0.8789	1.9600
Kubanka	Phosphorus, 20 lbs.	0.0488	0.2098	0.7853	0.7421	1.7860
Kubanka	Potassium, 100 lbs.	0.0280	0.2098	0.7828	0.8454	1.8660
Kubanka	None	0.0453	0.2098	0.7376	0.7383	1.7310

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ASH CONSTITUENTS OF WHEAT—CROP 1914

Variety	Fertilizer per acre	Sp. gr.	SiO_2 Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	Total P Percent	Inorganic P Percent	Organic P Percent	Total N Percent
Defiance	80 lbs. nitrogen.....	1.3991	0.016	0.005	0.005	0.033	0.146	0.436	0.012	0.179	0.135	0.346	0.009	0.337	2.092
Defiance	40 lbs. phosphorus.....	1.4166	0.021	0.005	0.004	0.035	0.142	0.431	0.011	0.172	0.133	0.393	0.017	0.376	1.643
Defiance	150 lbs. potassium.....	1.4128	0.016	0.003	0.004	0.033	0.135	0.412	0.009	0.116	0.124	0.375	0.008	0.367	1.578
Defiance	None	1.4174	0.018	0.003	0.004	0.041	0.147	0.437	0.014	0.121	0.137	0.426	0.013	0.413	1.828
Red Fife	80 lbs. nitrogen.....	1.4253	0.011	0.004	0.004	0.030	0.142	0.398	0.011	0.160	0.092	0.364	0.009	0.355	1.922
Red Fife	40 lbs. phosphorus.....	1.4282	0.012	0.004	0.005	0.029	0.145	0.405	0.017	0.123	0.140	0.399	0.016	0.383	1.668
Red Fife	150 lbs. potassium.....	1.4171	0.011	0.004	0.005	0.034	0.146	0.403	0.013	0.112	0.093	0.403	0.014	0.389	1.724
Red Fife	None	1.4241	0.015	0.005	0.005	0.030	0.156	0.437	0.016	0.114	0.119	0.412	0.017	0.395	1.794
Kubanka	80 lbs. nitrogen.....	1.4241	0.012	0.004	0.005	0.032	0.133	0.418	0.016	0.093	0.128	0.343	0.008	0.335	2.168
Kubanka	40 lbs. phosphorus.....	1.4147	0.005	0.003	0.004	0.029	0.134	0.436	0.004	0.093	0.108	0.397	0.008	0.389	1.714
Kubanka	150 lbs. potassium.....	1.4097	0.006	0.003	0.005	0.033	0.143	0.451	0.004	0.144	0.109	0.366	0.005	0.361	1.925
Kubanka	None	1.4171	0.010	0.004	0.005	0.033	0.140	0.442	0.041	0.142	0.123	0.385	0.008	0.377	1.751

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WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1915

Variety	Section 1700 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	Nitrogen, 120 lbs.....	10.583	2.125	1.875	4.180	2.1040	11.993	58.520	1.090	29.00	10.88	7.257	0.405	0.537	16.17
Defiance	Phosphorus, 60 lbs.....	10.185	1.958	1.970	3.837	1.5374	8.763	61.632	1.075	18.17	7.03	4.423	0.402	0.447	18.35
Defiance	Potassium, 200 lbs.....	10.480	1.870	1.985	3.732	1.5378	8.765	62.806	0.095	20.00	7.78	5.000	0.391	0.453	22.00
Defiance	None	9.833	1.945	1.923	4.175	1.5447	8.805	62.330	1.022	19.00	7.26	4.586	0.394	0.460	17.77
Red Fife	Nitrogen, 120 lbs.....	9.663	2.025	1.825	3.802	1.9711	11.235	58.605	0.848	30.80	11.82	7.681	0.373	0.516	19.27
Red Fife	Phosphorus, 60 lbs.....	10.233	2.180	1.940	3.195	1.4189	8.088	62.136	0.824	18.20	7.38	4.834	0.410	0.486	23.63
Red Fife	Potassium, 200 lbs.....	9.853	2.246	1.913	3.325	1.5160	8.641	62.551	0.860	21.17	8.39	5.452	0.426	0.506	25.40
Red Fife	None	9.728	2.045	1.920	3.227	1.4119	8.084	62.154	0.842	18.17	7.51	4.926	0.397	0.476	23.54
Kubanka	Nitrogen, 120 lbs.....	9.835	1.855	2.090	3.050	2.2383	13.247	55.093	1.049	41.70	15.48	10.126	0.367	0.487	33.85
Kubanka	Phosphorus, 60 lbs.....	9.655	2.003	2.013	2.940	1.6142	9.721	59.508	0.983	28.90	11.39	7.251	0.398	0.455	35.30
Kubanka	Potassium 200 lbs.....	10.598	2.060	2.023	3.015	1.7401	9.998	59.400	0.955	27.40	10.65	7.065	0.400	0.457	38.85
Kubanka	None	10.603	2.120	2.110	2.955	1.6702	9.645	54.128	1.023	28.70	10.91	7.338	0.384	0.441	36.97

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS—CROP 1915

Variety	Section 1700 Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 120 lbs....	0.0699	0.1600	0.7627	1.0213	2.1040
Defiance	Phosphorus, 40 lbs...	0.0418	0.1398	0.5312	0.6845	1.4953
Defiance	Potassium, 200 lbs..	0.0210	0.1328	0.5149	0.7573	1.5378
Defiance	None	0.0349	0.1328	0.5289	0.7502	1.5447
Red Fife	Nitrogen, 120 lbs...	0.0839	0.2307	0.6360	0.8737	1.9711
Red Fife	Phosphorus, 60 lbs..	0.0558	0.1600	0.4318	0.6671	1.4189
Red Fife	Potassium, 200 lbs..	0.0593	0.1818	0.4659	0.6865	1.5160
Red Fife	None	0.0663	0.1678	0.4380	0.6383	1.4119
Kubanka	Nitrogen, 120 lbs...	0.0628	0.1188	0.8504	1.2361	2.3241
Kubanka	Phosphorus, 60 lbs..	0.0558	0.0908	0.6641	0.8597	1.7054
Kubanka	Potassium, 200 lbs..	0.0558	0.1048	0.6176	0.9268	1.7054
Kubanka	None	0.0558	0.0978	0.6246	0.8713	1.6915

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WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1915

Variety	Section 1800 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	Nitrogen, 80 lbs.....	10.690	1.865	1.818	4.322	2.0128	11.552	58.826	1.071	28.80	11.02	7.292	0.366	0.466	16.97
Defiance	Phosphorus, 40 lbs.....	10.180	1.959	1.965	3.780	1.4814	8.523	61.128	1.027	18.30	7.09	4.252	0.401	0.442	13.42
Defiance	Potassium, 150 lbs.....	8.625	1.777	1.998	3.855	1.4814	8.523	62.946	1.030	20.70	7.97	5.027	0.375	0.416	21.37
Defiance	None	9.953	1.905	1.980	3.912	1.5934	9.162	60.174	1.051	20.50	8.35	4.982	0.333	0.465	18.05
Red Fife	Nitrogen, 80 lbs.....	9.203	1.987	1.860	3.587	1.7679	10.077	60.480	0.794	24.70	9.28	6.244	0.378	0.466	22.05
Red Fife	Phosphorus, 40 lbs.....	9.528	2.022	1.993	3.365	1.4050	8.009	61.988	0.813	18.00	7.27	4.913	0.390	0.471	23.02
Red Fife	Potassium, 150 lbs.....	9.975	1.965	1.813	3.385	1.5478	8.822	62.982	0.829	22.17	8.99	5.829	0.390	0.468	25.30
Red Fife	None	10.085	2.005	2.063	3.312	1.4707	8.383	62.044	0.755	19.40	7.73	5.053	0.390	0.447	24.62
Kubanka	Nitrogen, 80 lbs.....	9.658	1.985	2.088	3.280	2.2383	12.758	54.126	1.046	39.07	15.00	10.089	0.336	0.441	24.14
Kubanka	Phosphorus, 40 lbs.....	9.738	1.835	2.048	3.045	1.6142	9.201	59.436	0.933	26.40	10.81	6.965	0.374	0.435	27.97
Kubanka	Potassium, 150 lbs.....	11.683	1.880	1.850	3.052	1.7401	9.919	60.480	0.941	26.70	10.71	7.011	0.384	0.432	29.75
Kubanka	None	10.898	2.003	1.895	2.950	1.6702	9.520	59.773	0.909	27.50	11.10	7.060	0.391	0.427	28.18

FORMS OF NITROGEN IN WHEAT AS AFFECTED BY FERTILIZERS —CROP 1915

Variety	Section 1800 Fertilizer per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 80 lbs.....	0.0558	0.1740	0.7374	1.0440	2.0367
Defiance	Phosphorus, 40 lbs..	0.0418	0.1398	0.5312	0.6845	1.4953
Defiance	Potassium, 150 lbs..	0.0349	0.1460	0.5250	0.6783	1.4952
Defiance	None	0.0488	0.1538	0.4706	0.8291	1.6073
Red Fife	Nitrogen, 80 lbs....	0.0669	0.1958	0.5498	0.8265	1.7679
Red Fife	Phosphorus, 40 lbs..	0.0628	0.1678	0.4240	0.6454	1.4050
Red Fife	Potassium, 150 lbs..	0.0662	0.1678	0.4981	0.7141	1.5478
Red Fife	None	0.0662	0.1678	0.4330	0.6971	1.4707
Kubanka	Nitrogen, 80 lbs....	0.0699	0.1398	0.8621	1.0966	2.2383
Kubanka	Phosphorus, 40 lbs..	0.0523	0.1048	0.5569	0.8477	1.6142
Kubanka	Potassium, 150 lbs..	0.0628	0.0978	0.5681	0.9764	1.7401
Kubanka	None	0.0628	0.1048	0.5611	0.8905	1.6702

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WHEATS GROWN ON EXPERIMENTAL PLOTS—CROP 1915

Variety	Section 1900 Fertilizer per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent	Grams per 1000 Kernels
Defiance	Nitrogen, 40 lbs.....	9.653	1.730	1.905	3.895	1.8800	10.716	59.543	0.960	27.17	10.71	6.612	0.350	0.449	19.00
Defiance	Phosphorus, 20 lbs.....	9.940	1.785	1.935	3.700	1.5378	8.765	62.935	0.999	18.50	7.47	4.752	0.375	0.443	20.92
Defiance	Potassium, 100 lbs.....	10.203	1.577	2.100	3.330	1.4814	8.444	62.895	0.994	20.00	7.92	4.954	0.353	0.462	28.62
Defiance	None	10.085	1.826	1.920	3.797	1.5795	9.003	62.228	1.024	18.70	7.37	4.680	0.380	0.444	19.44
Red Fife	Nitrogen, 40 lbs.....	9.990	1.818	1.869	3.560	1.8521	10.557	59.678	0.963	28.70	10.88	7.478	0.343	0.472	20.96
Red Fife	Phosphorus, 20 lbs.....	10.245	1.820	1.935	3.355	1.4777	8.423	63.094	0.896	19.70	7.82	5.258	0.367	0.457	24.75
Red Fife	Potassium, 100 lbs.....	9.700	1.965	1.943	3.225	1.5409	8.783	63.828	0.833	22.30	8.65	6.219	0.383	0.453	26.89
Red Fife	None	10.043	1.862	1.978	3.347	1.4814	8.444	62.478	0.795	21.00	8.22	5.399	0.361	0.443	25.08
Kubanka	Nitrogen, 40 lbs.....	11.368	1.675	2.005	3.207	1.9919	11.354	57.654	1.051	28.00	11.55	8.073	0.400	0.407	35.35
Kubanka	Phosphorus, 20 lbs.....	11.968	1.785	2.005	2.995	1.6984	9.681	59.004	0.968	25.30	10.36	6.900	0.375	0.430	36.23
Kubanka	Potassium, 100 lbs.....	11.118	1.755	1.910	3.237	1.7262	9.839	60.678	0.959	25.17	10.38	6.851	0.363	0.444	93.13
Kubanka	None	11.425	1.805	1.958	3.000	1.7123	9.760	61.596	0.971	26.07	10.63	7.028	0.396	0.439	36.61

FORMS OF NITROGEN IN WHEAT AS AFFECTED BY FERTILIZERS —CROP 1915

Variety	Section 1900 Fertilizers per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Defiance	Nitrogen, 40 lbs....	0.0418	0.1740	0.6508	0.8812	1.8800
Defiance	Phosphorus, 20 lbs..	0.0349	0.1398	0.4753	0.7829	1.5378
Defiance	Potassium, 100 lbs..	0.0280	0.1328	0.4890	0.7268	1.4814
Defiance	None	0.0418	0.1538	0.5172	0.6547	1.5795
Red Fife	Nitrogen, 40 lbs....	0.0769	0.2028	0.6266	0.8199	1.8521
Red Fife	Phosphorus, 20 lbs..	0.0628	0.1538	0.4520	0.7181	1.4777
Red Fife	Potassium, 100 lbs...	0.0628	0.1460	0.5250	0.7239	1.5409
Red Fife	None	0.0699	0.1740	0.4690	0.6644	1.4814
Kubanka	Nitrogen 40 lbs.....	0.0769	0.1328	0.6403	1.0855	1.9919
Kubanka	Phosphorus, 20 lbs..	0.0628	0.1048	0.5569	0.9319	1.6984
Kubanka	Potassium, 100 lbs..	0.0769	0.0978	0.6106	0.9200	1.7262
Kubanka	None	0.0593	0.0978	0.6153	0.9014	1.7123

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ASH CONSTITUENTS OF WHEAT—CROP 1915

Section 1800

Variety		SiO_2	Fe	Mn	Ca	Mg	K	Na	Cl	S	P	N
Defiance	$NaNO_3$	0.018	0.005	0.004	0.046	0.149	0.466	0.010	0.083	0.143	0.366	2.0128
Defiance	P_2O_5	0.094	0.010	0.004	0.061	0.132	0.448	0.037	0.073	0.103	0.401	1.4814
Defiance	Kcl	0.018	0.005	0.004	0.040	0.141	0.416	0.018	0.084	0.101	0.375	1.4814
Defiance	Check	0.019	0.005	0.004	0.054	0.162	0.465	0.022	0.085	0.100	0.383	1.5934
Red Fife	$NaNO_3$	0.058	0.008	0.004	0.038	0.153	0.466	0.024	0.094	0.115	0.378	1.7679
Red Fife	P_2O_5	0.012	0.004	0.004	0.085	0.114	0.471	0.027	0.072	0.094	0.390	1.4050
Red Fife	Kcl	0.012	0.004	0.004	0.037	0.147	0.468	0.021	0.090	0.087	0.390	1.5478
Red Fife	Check	0.014	0.004	0.004	0.046	0.141	0.447	0.034	0.063	0.087	0.390	1.4707
Kubanka	$NaNO_3$	0.018	0.007	0.004	0.043	0.128	0.441	0.026	0.061	0.102	0.336	2.2383
Kubanka	P_2O_5	0.028	0.006	0.004	0.034	0.133	0.425	0.055	0.048	0.078	0.374	1.6142
Kubanka	Kcl	0.026	0.004	0.004	0.032	0.134	0.432	0.026	0.063	0.068	0.387	1.7401
Kubanka	Check	0.022	0.007	0.004	0.035	0.135	0.427	0.029	0.053	0.106	0.391	1.6702

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SHRUNKEN KERNELS NOT NECESSARILY HIGH IN PROTEIN

In the preceding tables we have the samples grown during two years of experimentation. Many of these samples, practically all those of 1915, the Defiance samples of 1914, and the samples of both the Fife and Kubanka grown with the application of nitrate are shrunken. These latter samples are not shrunken to anything like the extent of some of the others. I think that it is generally accepted as a fact that shrunken grains are higher than normal in protein. I acknowledge that I thought that this was an established fact. But there is no difference between the badly shrunken samples and the plumper ones that cannot justly be explained in some other manner. The samples grown with the application of nitrates in 1913, carried, in round numbers, 2.0 percent more protein than samples from the other plots. We find on an average a little greater difference in 1915. Our samples of 1913 are all fine, plump wheats, as the weights per 1,000 kernels show. In 1915 they were all more or less shrunken. The Defiance was so badly shrunken that we could sell it only for chicken feed. It would seem unreasonable to consider the excess of protein in the nitrate samples of 1915 due to their shrunken condition, when essentially the same difference existed in the 1913 crop, which was not shrunken. The other shrunken samples of 1915 are all low in protein but they are neither higher nor lower than the less shrunken samples of the same variety grown that season. In fact, the very badly shrunken samples of 1915, differ but little in their protein content from the plump, full-weight samples of 1914. The difference is in favor of the plump samples of 1914. The fact is that the shrunken condition of the samples seems to have nothing to do with the composition, but simply indicates that the process of filling was cut short, and that which would have been a large kernel, remained an incompleted structure. The character of the material, and the amount of it, with which the kernel was filled, was in these cases determined by the rust. The similarity in the composition of the crops of 1914 and 1915 is remarkable. Rust was very abundant in both seasons. The plants were a little more fully developed in 1914 than in 1915 at the time that the rust attacked the plants. The crop was materially better in 1914 than in 1915, but the composition of the wheat was, as stated, very similar. It is not to be understood that we had no fair crops in 1915, for this is not the case. We had as high as 40.8 bushels per acre, weighing 60 pounds to the bushel, and it was only the plots treated with nitrates that yielded crops of either Red Fife or Kubanka that weighed less than 60 pounds to the bushel, some of the Kubanka weighed 63 pounds, but the composition of the wheat was essentially the same as that of the badly shrunken Defiance, weighing from 49 to 53 pounds per bushel.

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These results seemed to make it worth the while to determine whether there is any difference in the composition of the large and small kernels of the same samples grown in a favorable season. The samples that we have, which will fulfill this condition, are those grown in 1913. We have arranged in the following table analyses of large and small kernels:

COMPOSITION OF LARGE AND SMALL KERNELS—CROP 1913

Variety	Fertilizer per Acre		Percent of Wheat	Average Wt. per Kernel	Nitrogen Percent	Protein Nx6.7 Percent	Phosphorus Percent	Potassium Percent
Defiance	80 lbs. nitrogen...	large	56.00	0.0397	2.349	12.390	0.395	0.422
		small	44.00	0.0239	2.342	13.347	0.390	0.475
Defiance	40 lbs. phosphorus	large	77.75	0.0417	2.210	12.595	0.444	0.439
		small	22.25	0.0284	1.982	11.299	0.435	0.426
Defiance	150 lbs. potassium	large	74.30	0.0433	2.207	12.582	0.406	0.423
		small	25.70	0.0302	2.014	11.479	0.412	0.413
Defiance	None	large	71.50	0.0425	2.228	12.700	0.412	0.457
		small	28.50	0.0293	2.077	11.837	0.426	0.450
Red Fife	80 lbs. nitrogen..	large	51.60	0.0398	2.637	15.032	0.405	0.467
		small	48.40	0.0289	2.496	14.226	0.405	0.464
Red Fife	40 lbs. phosphorus	large	49.60	0.0391	2.365	13.481	0.456	0.425
		small	50.40	0.0301	2.295	13.079	0.456	0.454
Red Fife	150 lbs. potassium	large	53.10	0.0390	2.447	13.945	0.454	0.413
		small	46.90	0.0318	2.394	13.644	0.426	0.437
Red Fife	None	large	41.00	0.0388	2.457	14.001	0.455	0.440
		small	59.00	0.0306	2.414	13.759	0.462	0.390
Kubanka	80 lbs. nitrogen...	large	45.00	0.0532	2.442	13.920	0.387	0.416
		small	55.00	0.0332	2.433	13.867	0.365	0.423
Kubanka	40 lbs. phosphorus	large	63.66	0.0490	2.141	12.202	0.413	0.463
		small	36.34	0.0339	2.046	11.659	0.396	0.502
Kubanka	150 lbs. potassium	large	65.30	0.0502	2.135	12.167	0.408	0.433
		small	34.70	0.0300	2.068	11.788	0.416	0.438
Kubanka	None	large	69.65	0.0529	2.118	12.073	0.427	0.482
		small	30.35	0.0298	2.085	11.885	0.412	0.474

The table has purposely been made full in the points essential in this case. These small kernels come from the top and bottom of the head and from the middle of the spikelet. We find, in the twelve pairs, a maximum difference of 1.30 percent. There is one other case with a difference of 1 percent. The other ten pairs differ by lesser amounts. The difference, however, is always in the same direction, in favor of the larger kernels. According to these results, neither the shrunken crops, nor the small berries, contain more protein than the large, plump ones.

We have now given the composition of the seed used, that of the three crops so far obtained, and the conditions under which the latter were produced. The Defiance was seed of our own growing, the Red

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Fife and Kubanka was seed obtained from the South Dakota Experiment Station. Our own seed was wheat which had been grown on the college farm for many years. The strain is accepted as pure and the variety well established. The Dakota seed was true to variety and pure. It is stated that acclimatization has but little or no influence upon the composition of the crop produced when the seed is transported, as in this case, from one locality to another. I accept this as established and attribute any changes in the character of the crop to local conditions, either of soil, or climatic, or both. The physical characteristics of the first crop were very different from the parent seed, this, however, was true of the crop from our own seed in a certain measure, but not to the same extent as for the crops produced from the Dakota seed. Both the Fife and the Kubanka berries were much larger and different in color. Being curious to learn how the 1913 crops grown in South Dakota would compare in composition with my crops, grown from the same seed, I obtained, through the courtesy of their Department of Agronomy, samples of this crop. My object was not simply to test the effect of change but to assure myself in regard to the effects of my fertilizer experiments, which I shall present later. At the present time I shall endeavor to present the general composition.

GENERAL COMPOSITION OF WHEATS IN 1913, 1914, AND 1915

Under the general consideration of the weather conditions I have pointed out one result which did very great injury, i.e., that these conditions brought about a very severe attack of rust. I have already touched upon the effects of this on the yield and weight per bushel, giving for the latter 62.3, 56.7, and 49.6 pounds in the respective years of 1913, 1914 and 1915. This was for Defiance from the check plots of Section 1800. The weight per bushel of the other varieties was not depressed in 1914 but was slightly depressed in 1915. This indicates that some of the wheat was badly shrunken. Each of the three varieties was severely attacked by the fungus.

Before I give the composition of the wheat for these three years, I wish to again state that my data do not answer the question relating to the effect of planting wheat after wheat on the composition of the second or third crop, and I cannot recall having seen any answer to this question. The growth of the plants, the yield per acre and the weight per bushel have been mentioned as indicating that there was no lack of plant food, but it must be admitted that all of these taken together lack in conclusiveness when we consider the composition.

For our present purpose, i.e., to give a general idea of the composition of these crops, we shall confine ourselves to the amounts of protein, starch, wet, dry and true gluten, and phosphorus. The varia-

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tion in the moisture, ash, fat, and crude fiber is too small to play any important part in our present discussion. We shall give the ash constituents to show how little they vary in the three seasons, although the wheats are of very different composition. We shall confine these to the check plots of a single section to avoid, as far as possible, varying conditions and confusion due to different fertilization, and also for the further reason that we have determined the ash constituents in the kernels of one section only. The series of checks given in the following table runs north and south through our land; had it been taken east and west, the individual data would have been different, a fact which we do not wish to evade; but the general results would have been the same, so far as the data actually acquired may be depended on to show:

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GENERAL COMPOSITION OF THE SEED USED AND THE CROPS OF 1913, 1914 AND 1915

	Protein Percent	Starch Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Sp. gr.
Average for Domestic Wheats	12.23	.....	26.46	10.31	.....	.....	.....
Average for Foreign Wheats	12.08	.....	25.36	9.82	.....	.....	.....
Red Fife, South Dakota, seed crop 1912	12.82	59.81	29.33	11.32	8.225	0.279	1.4127
Red Fife, South Dakota, crop 1913	13.27	62.28	28.43	11.41	8.550	0.320	.....
Kubanka, South Dakota, seed crop 1912	13.04	61.18	30.93	12.91	9.462	0.326	1.4334
Kubanka, South Dakota, crop 1913	13.32	16.01	29.33	12.37	9.220	0.351	.....
Red Fife, Section 1800, check crop 1913	14.43	61.88	28.83	11.55	8.340	0.462	1.4401
Red Fife, Section 1800, check crop 1914	10.22	63.14	25.77	10.42	7.460	0.412	1.4241
Red Fife, Section 1800, check crop 1915	8.38	62.04	19.40	7.73	5.050	0.390	.....
Kubanka, Section 1800, check crop 1913	12.05	63.37	25.33	10.63	7.570	0.423	1.4355
Kubanka, Section 1800, check crop 1914	9.98	62.59	26.30	10.96	7.440	0.385	1.4171
Kubanka, Section 1800, check crop 1915	9.52	59.78	27.50	11.10	7.060	0.391	.....
Defiance Seed used	13.46	61.47	30.66	11.74	8.504	.....	.....
Defiance, Section 1800, check crop 1913	12.14	61.83	25.07	10.22	7.313	0.416	1.4355
Defiance, Section 1800, check crop 1914	10.46	63.14	24.40	10.09	7.000	0.426	1.4174
Defiance, Section 1800, check crop 1915	9.13	60.17	20.50	8.35	4.980	0.383	.....

ASH CONSTITUENTS CALCULATED ON THE AIR-DRIED GRAIN FOR THE THREE YEARS 1913, 1914 AND 1915

	SiO_2 Percent	Fe Percent	Mn Percent	Ca Percent	Mg Percent	K Percent	Na Percent	Cl Percent	S Percent	P Percent
Red Fife, South Dakota seed	0.018	0.005	0.005	0.044	0.134	0.490	?	0.086	0.175	0.267
Kubanka, South Dakota seed	0.011	0.006	0.005	0.026	0.141	0.468	?	0.064	0.145	0.326
Red Fife, Section 1800, check crop 1913	0.017	0.006	present	0.038	0.150	0.444	0.010	0.135	0.113	0.461
Red Fife, Section 1800, check crop 1914	0.015	0.005	0.005	0.030	0.156	0.437	0.016	0.114	0.119	0.412
Red Fife, Section 1800, check crop 1915	0.014	0.004	0.004	0.046	0.141	0.447	0.034	0.063	0.087	0.390
Kubanka, Section 1800, check crop 1913	0.030	0.005	present	0.031	0.137	0.454	0.010	0.130	0.093	0.423
Kubanka, Section 1800, check crop 1914	0.010	0.004	0.005	0.033	4.140	0.442	0.041	0.142	0.123	0.385
Kubanka, Section 1800, check crop 1915	0.022	0.007	0.004	0.035	0.135	0.427	0.029	0.053	0.106	0.391
Defiance, Section 1800, check crop 1913	0.030	0.005	present	0.037	0.141	0.391	0.037	0.060	0.116	0.416
Defiance, Section 1800, check crop 1914	0.018	0.003	0.004	0.041	0.147	0.437	0.014	0.121	0.137	0.426
Defiance, Section 1800, check crop 1915	0.019	0.005	0.004	0.054	0.162	0.465	0.022	0.085	0.100	0.383

A COMPARISON OF COLORADO AND SOUTH DAKOTA WHEATS GROWN IN 1913

The preceding table gives the most important features in the composition of wheat and the averages for domestic and foreign wheats. Further, it gives the composition of the South Dakota seed and of the crop grown from it in South Dakota, also the same for the crops grown under our conditions. An unbiased comparison of these results leads to the conclusion that in 1913 no changes were produced, which might not have been found in samples grown from our own seed, under our own climatic conditions and on contiguous pieces of land, one-tenth of an acre in area. This is true in the case of all of the data given to show the composition of the samples. The nitrogen determinations were not made by the same analyist that did the earlier work and the ash-analyses were all made by a third one. All nitrogen and starch determinations were done in duplicate, so that neither the differences nor the uniformities which occur are attributable to accidents or errors. The methods used, except those used in determining the mineral constituents, were conventional ones.

The products of the three seasons, grown on the same plots of land and without fertilizers of any kind, vary greatly in their protein, much more markedly so than in their starch content. The highest percentage of starch found in our nine samples of crops grown is 63.37, the lowest 59.78, a range of 3.55 percent for the samples of three varieties of wheat in three years, with an average starch content of 61.9 percent. On the other hand, we have a maximum range of 6.05 percent in the protein, with an average of 10.7 percent. The ratio of starch to protein varies between relatively wide limits from 4.3 to 7.4. This high ratio is evidently due to the suppression of the protein and not due to any unusual increase in the amount of starch. The samples so far considered were grown on check plots and for reasons given above.

The results given for this series of checks taken year by year agree fairly well with the averages obtained for all of the plots, excluding those fertilized with nitrogen.

AN AVERAGE OF THE VARIETIES SECTION BY SECTION

In order to set forth more fully the general composition of the crops, the variation due to variety, and the effects of nitrates, I have averaged the varieties section by section including the check plots with those which received phosphorus and potassium respectively; this fact is indicated by the expression 3/3, meaning the average of these three plots each time. The averages for the nitrates have been made for the sections only. The three varieties are included in each average which is designated in the same manner as the other averages.

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AVERAGE COMPOSITION OF WHEAT—CROP 1913

		Protein Perct.	Starch Perct.	Wet Gluten Perct.	Dry Gluten Perct.	True Gluten Perct.	Phosphorus Perct.
Section 1700	Defiance 3/3.....	11.67	61.67	24.45	9.93	7.05	0.445
Section 1700	Red Fife 3/3.....	13.10	62.19	27.46	11.07	8.00	0.467
Section 1700	Kubanka 3/3.....	12.28	61.07	26.84	11.26	7.91	0.438
Average	.....	12.35	61.64	26.25	10.75	7.65	0.450
Section 1800	Defiance 3/3.....	12.16	62.32	24.69	10.05	7.15	0.422
Section 1800	Red Fife 3/3.....	13.84	61.66	27.68	11.22	8.18	0.460
Section 1800	Kubanka 3/3.....	12.00	62.53	25.78	10.76	7.57	0.414
Average	.....	12.66	62.17	26.05	10.68	7.63	0.432
Section 1900	Defiance 3/3.....	11.14	63.58	22.22	9.23	6.34	0.476
Section 1900	Red Fife 3/3.....	13.97	62.48	28.27	11.47	8.26	0.465
Section 1900	Kubanka 3/3.....	12.63	62.29	25.28	10.87	7.75	0.487
Average	.....	12.58	62.78	25.26	10.51	7.45	0.476
General average all plots without nitrates	.....	**12.53**	**62.19**	**25.85**	**10.65**	**7.58**	**0.453**
Section 1700	Nitrate plots 3/3...	14.89	62.24	34.79	13.77	10.13	0.433
Section 1800	Nitrate plots 3/3...	14.15	60.80	31.21	12.49	9.08	0.446
Section 1900	Nitrate plots 3/3...	13.48	59.76	27.73	11.40	8.12	0.451
General average for the nitrate plots	.....	**14.17**	**60.93**	**31.24**	**12.55**	**9.11**	**0.413**

AVERAGE COMPOSITION OF WHEATS—CROP 1914

		Protein Perct.	Starch Perct.	Wet Gluten Perct.	Dry Gluten Perct.	True Gluten Perct.	Phosphorus Perct.
Section 1700	Defiance 3/3.....	8.799	65.14	19.08	8.04	5.66	0.397
Section 1700	Red Fife 3/3.....	9.706	64.51	23.33	9.73	6.86	0.413
Section 1700	Kubanka 3/3.....	10.254	64.93	26.05	10.66	7.65	0.390
Average	.....	9.586	64.86	22.82	9.48	6.74	0.400
Section 1800	Defiance 3/3.....	9.607	63.97	21.61	9.02	6.17	0.398
Section 1800	Red Fife 3/3.....	9.838	63.28	23.49	9.55	6.84	0.405
Section 1800	Kubanka 3/3.....	10.240	64.00	26.12	11.05	7.47	0.383
Average	.....	9.895	63.75	23.74	9.87	6.83	0.395
Section 1900	Defiance 3/3.....	8.908	63.60	22.52	9.13	6.31	0.386
Section 1900	Red Fife 3/3.....	9.913	63.13	25.33	10.15	7.15	0.410
Section 1900	Kubanka 3/3.....	10.280	63.63	27.53	11.89	7.99	0.399
Average	.....	9.700	63.45	25.13	10.39	7.15	0.398
General average all plots without nitrates	.....	**9.416**	**64.02**	**23.90**	**9.91**	**6.91**	**0.398**
Section 1700	Nitrate plots 3/3..	12.174	61.35	31.05	12.83	9.14	0.395
Section 1800	Nitrate plots 3/3..	11.746	61.42	30.88	12.63	8.86	0.351
Section 1900	Nitrate plots 3/3..	10.901	63.10	28.91	11.83	8.00	0.359
General average	.....	**11.607**	**61.96**	**30.28**	**12.43**	**8.67**	**0.368**

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AVERAGE COMPOSITION OF WHEAT—CROP 1915

		Protein Perct.	Starch Perct.	Wet Gluten Perct.	Dry Gluten Perct.	True Gluten Perct.	Phosphorus Perct.
Section 1700	Defiance 3/3.....	8.78	62.26	19.06	7.36	4.67	0.396
Section 1700	Red Fife 3/3.....	8.27	62.28	19.21	7.76	5.07	0.411
Section 1700	Kubanka 3/3.....	9.79	57.71	28.33	10.98	7.22	0.394
Average	.....	8.95	60.75	22.20	8.70	5.65	0.400
Section 1800	Defiance 3/3.....	8.70	61.42	19.83	8.47	4.75	0.398
Section 1800	Red Fife 3/3.....	8.40	62.34	19.86	8.00	5.27	0.390
Section 1800	Kubanka 3/3.....	9.55	59.90	20.20	10.70	7.01	0.383
Average	.....	8.89	61.62	19.96	9.06	5.68	0.390
Section 1900	Defiance 3/3.....	8.74	62.37	19.07	7.59	4.46	0.369
Section 1900	Red Fife 3/3.....	8.55	63.47	21.00	8.23	5.63	0.334
Section 1900	Kubanka 3/3.....	9.76	60.43	25.51	10.46	6.93	0.378
Average	.....	9.01	62.09	21.86	8.76	5.67	0.360
General average all plots without nitrates	.....	**8.95**	**61.35**	**21.34**	**8.84**	**5.67**	**0.383**
Section 1700	Nitrate plots 3/3...	10.88	58.99	27.99	10.71	7.39	0.364
Section 1800	Nitrate plots 3/3...	11.46	57.81	27.86	11.79	7.87	0.360
Section 1900	Nitrate plots 3/3...	12.16	57.41	33.83	12.73	8.36	0.382
General Average for the Nitrate plots	.....	**11.50**	**58.07**	**29.89**	**11.74**	**7.87**	**0.369**

There is one big fact evident, namely, that there is a great difference in the composition of the products obtained, whether taken by variety, or by plot. There was a depression of the proteids in 1914, and a further one in 1915. This is not true of the starch, for we find very similar figures for 1913 and 1915, the best and the worst crop. The samples produced with the application of nitrates have been averaged by themselves for the purpose of bringing out the effects of the nitrates in contrast with the more normal samples grown either without any fertilizer, or with such as do not radically disturb the composition of the products.

The data presented in the various tables make it clear that we may safely consider the nitrogen as the element most susceptible to the causes of these differences, and at the same time the most important one. There are differences in the mineral constituents, some of which can be explained, and the ratio of gliadin to glutenin is much closer in the best than in the worst of the three. These may, however, be neglected for the present time and the protein alone be taken into consideration. The starch varies too little in amount and too irregularly to be of much significance, though this too may be affected by the nitrogenous compounds in the wheat. The wet, dry and true gluten are so closely and regularly connected with the total protein that there would be no object in attempting to consider them at all in this connection. It seems probable, then, that, if we can make out what has caused the

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differences in the protein content of the three crops we will be justified in asserting that this is the cause that has determined the character of our wheats for 1914 and 1915.

The yield, weight per bushel, and the physical properties of the 1914 crop were all that we could wish, and I had no notion of the existence of any such facts as we find, pertaining to the composition, till the analyses revealed them. This was also in part true of the 1915 crop, for even in this crop 21 of the 24 plots planted to Red Fife and Kubanka yield from 21.95 to 40.83 bushels per acre, and the wheat from these 21 plots weighed from 60 to 63 pounds per bushel, but as appears from the average composition exhibited in the preceding table, the wheat is very inferior.

CAUSES OF INFERIOR WHEAT GROWN IN 1914

The causes which may have produced these results are, in the first place, lack of fertility, in the second place, excess of water and improper temperature which we will include under the term climatic conditions, and in the third place, the rust that developed upon the plants.

Lack of Fertility Not Responsible

In regard to the first cause, we have previously stated that we have no data of such convincing force that we feel entirely satisfied to assert that there might not have been something lacking in this respect, either in the quantity present or in its ratio to other plant foods. Nevertheless, these data convince me most thoroughly that this was not the case. The facts that appear to me as really conclusive that the very low protein content of the wheat in 1914 and 1915 was not due to this, i.e., lack of fertility, are the luxuriant growth of the plants, the yield of wheat, and its weight per bushel.

On the theory that the carbohydrates are deposited at or near the end of the plant's activity, and that the plumpness and weight per bushel depend upon the degree of perfection with which this process is carried out at the time of maturity, it may be suggested, as is frequently stated in the literature of this subject, that the volume of the crop would necessarily correspond to a low protein content. This suggestion does not apply, for in 1913 our Defiance check plots yielded an average of 41.1 bushels, weighing 62.3 pounds per bushel, with 11.86 percent of protein; the same plots in 1914 yielded an average of 31.1 bushels, weighing 56.7 pounds per bushel, with 9.383 percent protein. We need not confine this statement to the Defiance. The Fife plots treated with potassium in 1913 yielded 32.67 bushels per acre, weight per bushel 63.75 pounds, average protein 13.81 percent; the same plots with the same treatment yielded in 1915, 32.16 bushels per acre, weight

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per bushel 60.6 pounds, average protein 8.30 percent. The Kubanka check plots yielded in 1913 an average of 34.1 bushels per acre, weight per bushel 63.1 pounds, average protein 12.28 percent; the same plots in 1915 yielded 32.8 bushels per acre, weight per bushel 62.6, average protein content 9.64 percent. An explanation of the difference in the protein content can not be based on the ground that the volume of the crop corresponded to a large increase in the percentage of the starch or other carbohydrates. The percentages of starch remain constant within very narrow limits.

If any deficiency in fertility actually existed, it would probably correspond to the deficiency in the grain and this is in the nitrogen content. The growth and color of the plants ought to reveal any so great a deficiency as would correspond to the depression of the nitrogen that we find. Further, we find direct proof that this is not the case, in that we find a depression in the average amount of the protein present in the grain grown on the respective plots to which a liberal application of nitrogen had been made. We have for the average amount of protein in the grain produced on such plots in 1913, 14.17 percent, in 1914, 11.50 percent and in 1915, 11.50 percent. Some of the samples included in these averages, especially in 1914 and 1915, were badly shrunken and, according to the accepted theory, should have been very high in nitrogen; others of them were, from the physical standpoint, perfect wheats. The amount of nitrogen applied to these plots varied from 40 to 120 pounds per acre, so there could not possibly have been any dearth of nitrogen.

The considerations here presented may fail to satisfy some, but they appear to me to prove conclusively that the cause of the inferior composition of the wheats produced in 1914 and 1915 can not be attributed to lack of fertility.

Cannot Be Charged to Climatic Conditions

The question of climatic influences resolves itself into several phases each of which may be of varying importance, i.e., the total amount of water received by the crop, the manner of application, as irrigating water or as rain, or, stated otherwise, whether the soil alone or both the soil and the plant is wet, the time of application or distribution of the rain, the temperature, cloudiness, winds, etc. The mean temperature and air movement in the years of good and bad wheat were so similar, especially during the month of July and the early part of August, including the period from blossoming till maturity, that it is difficult to believe that these factors were responsible for the differences in the quality of the grain. The mean temperature for July, 1913, was 66.8 degrees, and in 1915 it was 64.7 degrees. The early part of the month in 1915 was warmer than in 1913, but there were great deviations from the mean in either year. There was a

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difference in the amount of cloudy weather and the distribution of the water. The amount of water received by the crop during the respective seasons was the same, 19 inches, in 1913 we applied to most of the plots 12 inches of water and the rainfall was 7 inches (6.77), in 1915 we applied 6 inches and the rainfall was 13 inches. This fact relieves me from the necessity of considering the quantity of water used as a cause of these differences, but if it were necessary to do so, I would take the ground that a variation in the amount of water from 12 to 36 inches would not produce these results. We shall discuss this subject later. For the cases in hand, I shall consider the question of the effect of the amount of water eliminated by the fact that the water received during the months of May, June, July and the early part of August, or throughout the growing period of the crop, was so nearly the same that we are justified in neglecting the difference, especially as this difference pertains largely to the month of April, the time of seeding. The fact is that the total water received by the crop of 1915, was less than in 1913, the season when we obtained wheat of the best quality. These considerations justify us in dismissing the direct influence of the climatic conditions as the cause of the poor quality of our 1914 and 1915 crops. It is not intended to deny that the climatic influences affect the quality of wheat crops in some measure, but it is intended to assert that the inferior quality of the crops here considered was not due to the direct influence of climatic conditions.

Rust Chiefly To Blame For Poor Quality

I ascribe the poor quality of the wheat almost wholly to the effects of the rust that developed during the early days of August in 1914 and during the latter part of July in 1915. The earlier varieties of grain apparently escaped serious injury in 1914, when our maximum yield reached 55.5 bushels of wheat, weighing 64.5 pounds per bushel, and our next highest was 54.5 with the same weight per bushel. These two are given because they were obtained with different fertilizers. The rust appeared a few days earlier in 1915 and there was no question about its affecting the yield of each of the varieties. The Defiance was very seriously injured, the yield on one plot was reduced to less than 9 bushels per acre and the kernels were no more than dried out, empty sacks, which, contrary to the statements that I have found on this subject, were not remarkably high in protein, but were 20 percent lower than good kernels grown with the same fertilization on this ground the preceding year. I have found but one analysis of rusted wheat; this was published by Mr. F. T. Shutt, Chemist, Dominion Experimental Farms, Canada, Abstract in Experiment Station Record, Vol. XVI, p. 585. Mr. Shutt gives analyses of rusted and rust-free straw and also of grain. The grain from rust-free wheat contained 10.50 percent proteid, that from rusted wheat 13.69 percent. Mr. Shutt

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says of this: "In other words the growth of the rust arrests development and induces premature ripening, which, as we have seen, means a straw in which still remains the elaborated food and a grain small, immature, rich in protein and deficient in starch."

Prof. H. Snyder, in Minnesota Station Bulletin No. 90, Abstract E. S. R., Vol. XVI, p. 1074, gives the analyses of some rusted wheat-straws from which it appears that rust-free straw contains a little over one-half as much protein as badly rusted straw. The Abstract continues: "Wheat from rusted plants contained a higher percentage of protein, fiber and ash than some fully matured grain from rust-free plants grown under the same conditions. The percentage of carbohydrates was highest in the sound samples. Some of the rusted wheat samples contained as high as 19.30 percent of protein." These are the only references to the effects of rust upon the composition of the plant and the grain produced that I have found. McAlpine, in his book "The Rusts of Australia", p. 65, quotes the preceding statement of Shutt's with approval, but adds nothing to it.

Our Results Contrary To Prevailing Opinion

The fact is that we have in 1914 and 1915 wheat which is very similar in composition but very different from wheat produced on the same ground in 1913, and so far I have not given any cause for the difference, but have stated that I believe it to be due to the severe attacks of rust which prevailed during these years. It will be noted that the prevailing opinion is that wheat grown on affected plants is richer in protein than such as is matured on unaffected plants; it is also stated that shrunken wheat is higher in nitrogen than well-filled wheat. This may be correct, but it is certainly not the case with our wheat nor is the percentage of starch perceptibly affected, as is shown by the percentages of starch in the crops of 1913 and in 1915 grown without application of nitrates. The average percentage of starch in the 27 samples of 1913 is 62.2, and for the same number of samples in 1915, grown under the same conditions of fertilization, the average is 61.5. There is a difference of only 0.7 of 1 percent in favor of the crop of higher quality. We must frankly admit that our results are contrary to the prevailing opinion on this subject.

THE NITROGEN CONTENT

In 1913 we studied the development of the nitrogen compounds in the plant from time of blooming till maturity. It is entirely sufficient for our present purposes to follow the course of the total nitrogen. This will be found in detail for the crop of 1913 on page 36 of Bulletin 208. The percentages are given for the fresh plants, but the percentages of dry matter are given on page 34. The variety used for these may be used to recognize the corresponding sample of grain given in

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this bulletin. The samples grown with the application of nitrogen are again left out of consideration. The total nitrogen in the stems and leaves remained fairly constant till the end of July, when they showed a very decided decrease, in spite of the fact that the plants were drying out, amounting to from approximately 30 percent to 50 percent. On the other hand, the total nitrogen in the heads ran fairly constant till the end of July, when it suddenly increased from an average of 0.6967 to 0.9868 percent, practically 0.3 of 1 percent in five days (29 July to 4 August) and the head at that time was rapidly increasing in weight. There must have been a very active movement of nitrogen from the plant to the seed at that time. The wheat was cut on 6 and 7 August when it was fully ripe. This wheat averages 12.58 percent protein (N x 5.7).

Low Nitrogen Content In 1915 Due to Rainfall Causing Leaching or Impairing Transpiration

It was impossible for us to repeat this portion of our study in 1914 but we were fortunately able to take it up again in 1915. The full record of this work is given in Bulletin 217. The plants were from 10 to 14 days later in their development and were more succulent than in 1913. The succulency of the plant was probably due to the frequent light rains and heavy dews. The plants are poorer in nitrogen irrespective of the fertilizer applied, even after allowance has been made for the greater quantity of water in the plant. This might be due to three causes, exhaustion of the soil, leaching due to the almost continuously wet condition of the plant, or to a greatly retarded transpiration. Inasmuch as this difference is as great in the case of the plants that were grown with a continuous, artificial supply of nitrogen as in those which were grown without any, it is probably not due to deficiency in nitrogen, and if there be no other causes than those suggested, it must be due either to leaching or to impaired transpiration. This is, in either case, an effect of the weather. The samples of stems and leaves taken from the same set of plots on 29 July, 1913, and 30 July, 1915, were quite close to one another in their nitrogen content, but this was not true of the heads which in 1915 were materially lower than in 1913. It is evident that in both years about this time a very active transference of nitrogen from the plant to the head began. On 27 July, 1915, the heads on the Fife check plot contained 0.5247 percent and on 30 July, 0.6324 percent nitrogen. The drying out of these plants had not yet begun to take place. At about this time in both 1914 and 1915 the wheat became very rusty, but the wheat in 1914 was more advanced, by 5 or 6 days, than in 1915. In fact, we had had up to this time a very favorable season in 1914. This date is the turning point in the character of our respective crops. In 1913 the nitrogen in the plants de-

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creased regularly till the wheat was ripe. The stems and leaves dried out and the dry matter increased very greatly, but it was poorer in nitrogen than the plant had been at an earlier date. The heads increased in weight and dry matter, but most of all in nitrogen. On 25 July the heads of plants from plots which had received no dressing of nitrogen contained 0.8495 and the heads of plants from the same plots on 5 August contained 1.2463 percent of nitrogen. Samples taken from other plots between these dates indicate that practically the whole of this change took place between 29 July and 4 August. This wheat was free from rust, ripened naturally and was cut on 6 and 7 August. The average protein content of the samples of this variety grown without the application of nitrogen was 13.63 percent (N x 5.7).

I have pointed out that on 30 July the plants of the 1915 crops contained approximately the same amount of nitrogen as in 1913. From this date till that of full ripeness of the grain, the crops acted entirely differently. There was some increase in the nitrogen of the heads, but it was in no measure comparable to the change that took place in 1913. On 30 July the heads from a check plot averaged 0.6486, on 12 August heads from the same plot averaged 0.7828 percent nitrogen. During 11 days in 1913 we found that the nitrogen in the heads increased from 0.85 to 1.25 percent; in 1915 we found that they increased from 0.65 to 0.78. This apparent increase itself is doubtful when we consider the drying out which took place. On the other hand, we found that the stems and leaves did not diminish in their nitrogen content from this date on till that of ripeness as in 1913. On 6 August, the earliest date on which the leaves and stems were taken together, the average nitrogen content of the plants grown without the application of nitrogen was 0.2371 percent and that of the heads 0.6834 percent; on 12 August the plants and leaves contained an average of 0.2703 and the heads 0.7825 percent. The increase in the heads is at best very small, and, owing to the drying out and relative increase in dry matter, is a little doubtful. This wheat was harvested 16 August in good condition, except for the rust. The average protein content of this wheat was 8.41 percent. This average is 5.22 percent below that for the season 1913.

Rust Was Severe In 1915

We unfortunately were not able to follow this feature of our study in 1914. We can, however, record the fact that we had very favorable conditions up to the end of July, when we had a heavy shower which beat down our grain and rust followed. The grain was more advanced in its development when this happened than it was in 1915 when the rust attacked it. We do not know that the nitrogen transfer was practically stopped in 1914 as it was in 1915. The effect, however, on the composition of the wheat was almost the same. The aver-

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age protein content of the 1914 crop for this variety of wheat was 9.82 percent against 13.63 in 1913. This is a very surprising result considering the advanced stage of development of the wheat at the time of the attack. My opinion at the time was that the crop was almost safe against this kind of injury, but it evidently was not. According to our observations of 1913 and 1915 this effect is very probable if the attack took place, as it must have done just at, or during the period of most active transfer. In 1915 the rust was very bad, I have no measure by which I can express the severity of the attack, but it is evident from the data given that it practically stopped the transfer of nitrogen to the heads, which is equivalent to saying the kernels. If it did this in 1915, we argue that it did the same in 1914, and that this is the cause of the low protein content of the grain.

It may be true that the weather influenced the course of the development; it may also be true that the succession of crops may have been ill-advised, still, on 30 July, 1915, the nitrogen in the plants compared favorably in quantity in the stems and leaves with that present in 1913, and had the normal transfer taken place we should have had excellent wheat, for the plants were at this time large and thrifty, and the nitrogenous material already accumulated appeared ample to produce wheat of good quality, but, as we have seen, this did not take place, and we had wheat with 8.41 percent of protein. The observations of Shutt and Snyder on the high proteid content of rusted wheat-straw are in harmony with this view.

We have many samples of shrunken wheat in the crops of 1914 and 1915, but these samples are not high in nitrogen, which we interpret as the natural result of the stoppage of the transfer of the nitrogen. It seems that the movement of the carbohydrates is also interfered with and the shriveled wheat represents practically the condition of the kernel at the time of the attack. Some growth of the kernel takes place after the attack but it is so much less than would normally take place that it does not make the above statement wrong.

Deposition of Nitrogen and Starch Takes Place Simultaneously

This is not the view generally held, so far as I have been able to gather. The prevalent view is that the nitrogenous components of the kernel are the first and the carbohydrates the last to be laid down, so that shrunken kernels are considered to be caused by deficiency of carbohydrates, chiefly starch. I have already called attention to the fact that the percentage of starch in the samples of 1913 and 1915 are very nearly alike, though the weight of the kernels is very different, as the average weight per 1,000 kernels for the respective years may indicate in a general way. The weight per 1,000 kernels in 1913 averaged 38.35 grams, in 1915 26.61 grams, a difference of 11.74 grams per 1,000

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kernels, or 44 percent in favor of the 1913 crop. The difference in the average percentage of starch, taking all the samples except those grown with nitrates, is 0.84 percent. One hundred grams of the shrunken wheat contained practically the same amount of starch as a like quantity of the good wheat, and it contained less protein by 3.58 grams. This would seem to indicate that deposition of nitrogen and starch takes place at the same time—or if the deposition of one was hindered more than the other, the deposition of the nitrogen was hindered more than that of the starch.

VARIATION IN AMOUNT OF CRUDE FIBER

No feature in the composition of the crops produced during these three seasons is more marked in its variation than the percentage of crude fiber. In 1913 it was, perhaps, a little below the average for wheat in general—it may be taken roughly at 2.60 percent for 1913—in 1914 it was higher, about 3.00 percent, and in 1915 it was very high, about 3.7 percent. It will be observed that this is roughly inversely proportional to the absolute weight of the wheat. In other words, the frame-work of the cells had been completed and probably but little or no cellulose would under any conditions have been added to the kernels subsequent to the period at which the rust attacked the plants. The rust stopped the transfer of the filling material from the plant to the kernels, and left the ratio of cellulose to the other constituents abnormally high and the kernels shrunken.

The ash, as determined, is probably about 0.1 percent too low, owing to the losses in making the determination, but this loss is common to all the determinations and in the same direction, so that the averages are not very much disturbed. The individual determinations are comparatively close together, ranging in the case of Section 1800 from 1.700 to 1.995 for the year 1913, from 1.692 to 2.017 in 1914, and from 1.777 to 2.022 in 1915. These data include the three varieties and the different fertilizations. The averages for the three years, 1913, 1914 and 1915 are, for the grain grown on Section 1800, 1.925, 1.817 and 1.778 percent of ash respectively. The statement of the ash constituents has been given in percentages of the air-dried grain instead of percentages of the ash, which reduces the numbers given in the statement. Disregarding the chlorin and sulphur in the present statement, the greatest variations will be found in the phosphorus and potassium. These two are perhaps the most important ash constituents, at least they are in our problem, so far as now developed. The average amount of phosphorus in the grain (all three varieties taken) grown on Section 1800 in 1913, 1914, and 1915, was 0.432, 0.388 and 0.382 percent respectively, and the average amount of potassium was 0.441, 0.448 and 0.426 percent. While these averages conceal the differences

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in the individual samples, they serve to show that the different seasons, including all the factors, made but little difference in the average percentages of these elements in the grain, though the development of the kernels and their composition, especially in regard to nitrogen, was very different. While I believe, and have so stated, that very small differences expressed in percentages of air-dried grain, very probably have a big significance in regard to the properties of the wheat, and in relation to the effects of fertilizers, and perhaps, also of the seasons. I doubt, however, that we have any data which can be properly so interpreted, still the above averages justify the inference that the relative amounts of ash were not affected greatly by the different conditions prevailing during the three seasons; in other words, the whole development of the plant moved forward in the same manner and relative measure up to the time that the rust interrupted the transfer of matter to fill out the grain. We have no analyses of the plants, giving the ash constituents at such periods in their development that we can use the results in this connection. This is to be regretted, for had we analyses representing plants before and after this period of rapid transfer, it might give us some further useful data.

These results are in close agreement with the conclusions of Brenchley and Hall, who say: **"For the filling of the endosperm, each plant possesses as it were a special mould, and continually moves into the grain uniform material cast into that mould, possessing always the same ratio of nitrogenous to non-nitrogenous materials and ash."***

THE EFFECTS OF IRRIGATION

Our object in this work was to ascertain what we may consider characteristic of Colorado wheats and the factors to which this may be due. I have presented the crop of 1913 as probably the most nearly normal wheat that we have grown up to the present time, and I have justified myself in doing so by presenting the abnormal characteristics of the crops for 1914 and 1915, and the causes for the same. One of the factors which enters into our problem is the effect of water, particularly when applied as irrigating water. This question has already occurred in the consideration of the causes for the inferior quality of our 1914 and 1915 crops. In this connection I treated it in the most summary manner, principally because it is a definite and distinct problem. During the seasons of 1913 and 1914 I selected four plots to which I applied a second irrigation four weeks subsequent to the first one and equal in quantity, namely, I aimed to apply 1 acre-foot at each irrigation and to see what effects it produced upon the yield and character of the grain.

* W. E. Brenchley and A. D. Hall, "Development of the Grain of Wheat," Journal Agricultural Science, Vol. 3, Part 2, p. 215; also Rothamsted Memoirs, Vol. 8.

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Our experiments yielded no results that we could interpret as showing conclusively that this amount of water made any difference in the yield, weight per bushel, or composition of the grain. There were differences in the composition of the grain from the different plots, but they were small and irregular, so that we attributed the differences observed to the differences in the plots themselves and not to the differences in the amount of water applied.

I learned, very fortunately, that a systematic study of the effects of the fertility of the soil upon the duty of water and at the same time the effects of different amounts of water upon the amount of grain and dry matter produced, was being made at Boise, Idaho, by the U. S. Department of Agriculture, Irrigation Investigations. I further learned that they were not studying the effects of these conditions upon the composition of the grain. Mr. Don H. Bark, the irrigation engineer in charge, was kind enough to furnish me with samples of the grain produced, together with detailed cultural notes. The samples represent two years work and constitute most excellent material illustrative of this subject, especially the samples of the second year, which were grown wholly under Mr. Bark's supervision.

The samples representing the first year's work were produced under a co-operative system. The variety grown in 1913, the first year, was Dicklow spring-wheat. There was no perceptible difference in the physical properties of these kernels. They were all plump, but many of them were small or only medium in size and the weight per bushel was generally less than 60 pounds; some samples were as low as 52 pounds. The time from planting till harvest was in most cases 128 days.

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DICKLOW SPRING-WHEAT, BOISE, IDAHO—CROP 1913

Spring-Wheat	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Dicklow, 0.76 ft. water applied	9.508	1.953	1.778	2.982	1.427	8.133	65.542	1.249	14.27	5.79	4.036	0.404	0.479
Dicklow, 1.31 ft. water applied	9.503	1.905	1.710	2.817	1.532	8.687	66.076	1.656	15.83	6.33	4.446	0.432	0.488
Dicklow, 2.28 ft. water applied	9.388	1.908	1.718	2.875	1.464	8.343	64.926	1.703	14.40	5.96	4.207	0.392	0.490
Dicklow, 0.71 ft. water applied	9.015	1.907	1.828	2.875	1.662	9.476	64.746	1.484	17.90	7.42	5.307	0.410	0.494
Dicklow, 1.00 ft. water applied	9.223	1.840	1.890	2.900	1.477	8.417	65.304	1.644	16.73	6.68	4.807	0.397	0.546
Dicklow, 1.24 ft. water applied	9.163	1.922	1.833	3.057	1.508	8.596	66.258	1.519	17.37	7.00	5.079	0.401	0.534
Dicklow, 0.99 ft. water applied	9.535	1.949	1.783	3.062	1.556	8.864	66.592	1.602	15.53	6.27	4.435	0.381	0.491
Dicklow, 1.62 ft. water applied	9.575	1.920	1.660	2.912	1.573	8.966	64.602	1.525	16.50	6.69	4.708	0.399	0.512
Dicklow, 2.33 ft. water applied	9.428	1.896	1.738	2.933	1.555	8.864	65.178	1.549	16.73	6.62	4.771	0.389	0.491
Dicklow, 0.66 ft. water applied	9.093	1.771	1.878	2.810	1.584	9.028	66.492	1.715	17.79	7.06	5.101	0.363	0.498
Dicklow, 1.39 ft. water applied	9.390	1.839	1.765	2.962	1.337	7.181	66.150	1.495	14.47	5.79	4.194	0.353	0.457
Dicklow, 2.19 ft. water applied	9.355	1.795	1.713	2.905	1.410	8.037	66.744	1.421	15.20	5.94	4.115	0.322	0.504
Dicklow, 2.34 ft. water applied	9.618	2.141	1.760	3.412	1.568	8.939	65.898	1.404	16.20	6.67	4.752	0.427	0.501
Dicklow, 2.68 ft. water applied	9.493	1.984	1.830	3.037	1.522	8.675	64.314	1.432	16.33	6.39	4.497	0.414	0.560
Dicklow, 3.28 ft. water applied	9.453	2.030	1.755	3.112	1.608	9.156	63.486	1.415	17.23	6.99	5.016	0.433	0.551
Average	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....	0.395	0.506
Winter Wheat, Boise, Idaho													
Turkey Red, 0.47 ft. water applied	9.078	1.918	1.485	2.763	1.853	10.563	64.116	1.455	21.33	8.49	6.302	0.407	0.546
Turkey Red, 0.89 ft. water applied	9.138	1.913	1.520	2.712	1.855	10.573	64.602	1.507	20.44	8.19	6.105	0.393	0.517
Turkey Red, 0.93 ft. water applied	9.870	1.943	1.505	2.800	1.869	10.653	65.734	1.136	20.63	8.20	6.014	0.412	0.526
Average	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	....	0.404	0.530

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SPRING-WHEAT, BOISE, IDAHO

Spring-Wheat	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Dicklow, 0.76 ft. water applied.....	0.0140	0.1828	0.4892	0.7909	1.4269
Dicklow, 1.31 ft. water applied.....	0.0245	0.1258	0.5021	0.8798	1.5322
Dicklow, 2.28 ft. water applied.....	0.0280	0.1328	0.4892	0.8137	1.4637
Dicklow, 0.71 ft. water applied.....	0.0558	0.1678	0.5660	0.8728	1.6624
Dicklow, 1.00 ft. water applied.....	0.0314	0.1748	0.3880	0.8824	1.4766
Dicklow, 1.24 ft. water applied.....	0.0280	0.1748	0.5825	0.7228	1.5081
Dicklow, 0.99 ft. water applied.....	0.0245	0.1608	0.4974	0.8728	1.5555
Dicklow, 1.62 ft. water applied.....	0.0245	0.1818	0.5300	0.8367	1.5730
Dicklow, 2.33 ft. water applied.....	0.0245	0.1818	0.3806	0.9681	1.5550
Dicklow, 0.66 ft. water applied.....	0.0245	0.1608	0.5440	0.8546	1.5839
Dicklow, 1.39 ft. water applied.....	0.0280	0.1398	0.4194	0.7493	1.3365
Dicklow, 2.19 ft. water applied.....	0.0245	0.1748	0.4361	0.7946	1.4100
Dicklow, 2.34 ft. water applied.....	0.0349	0.1748	0.4917	0.8669	1.5683
Dicklow, 2 68 ft. water applied.....	0.0280	0.1748	0.4986	0.8206	1.5220
Dicklow, 3.28 ft. water applied.....	0.0314	0.1888	0.5184	0.8694	1.6080
Winter-Wheat, Boise, Idaho					
Turkey Red, 0.47 ft. water applied...	0.0628	0.1398	0.5383	1.1122	1.8531
Turkey Red, 0.89 ft. water applied...	0.0488	0.1468	0.5756	1.1836	1.8548
Turkey Red, 0.93 ft. water applied...	0.0384	0.1818	0.5721	1.0766	1.8689

Amount of Water Applied Does Not Affect Protein Content

These wheats are not shrunken, but the kernels are very uneven in size. It will be noticed that these wheats are a little higher in starch than our samples for 1913, when our Defiance on Section 1900 averaged 63.58 percent though the other varieties averaged lower, 61 and 62 percent. The percentage of true gluten is very low. The average percentage of phosphorus is lower than in our wheats and that of the potassium is markedly higher. These differences are consistent throughout the series of samples representing the Dicklow variety. To what these differences may be due is not the question that the samples are presented to answer, the question is: "What has been the effect of different amounts of water?" The table shows that the range in the percentage of crude protein is from 7.181 to 9.476, a difference of 2.3 percent. Is this difference due to the amount of water added, or is it due to differences in the land on which the wheat was grown? The wheat carrying 9.476 percent protein was grown with 0.71 foot of irrigating water, which is the lowest amount applied, except in one case, and this, with the least amount of water, produced wheat with 9.028 percent protein. The lowest percent of protein, 7.181, is found in wheat produced with the application of 1.39 acre-foot; with these exceptions the wheat runs uniformly within a limit of 1 percent, which may be due to differences of soil, for these samples were grown by different parties who were co-operating. We have pointed out that two of the wheats with high percentages of crude protein were pro-

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duced with less than 0.75 foot of water to the acre. On the other hand, the second highest percentage of protein, 9.156 percent, is found in wheat produced with the application of the maximum amount of water, 3.28 feet to the acre, and the next highest percentages occur with the application of 1.62 and 2.34 feet. The total range of the percentages of protein is so limited and the differences that we find being no greater than is found on different plots of land of the same character, and receiving the same treatment, we consider that these experiments, in so far as they are conclusive, indicate no relation between the amounts of water applied and the percentage of protein contained in the kernels. The total lack of any relation between the water applied and the variation of the percentage of protein produced, supports this view.

The winter-wheat given was harvested 340 days from planting. How much water fell as rain during the autumn and winter months is not given in the notes, nor is the date of ripening, but I take it that this date and that of harvesting were close together. This wheat is plump, with a great deal of yellow-berry or mealy wheat. The yields for irrigated wheat were very low, 3.7, 12.29 and 17.5 bushels to the acre. The amounts of water applied as irrigating water were 0.47, 0.89 and 0.93 acre-foot, and the analyses throughout are almost identical, showing a low percentage of protein for this variety, 10.6 percent, but it is very near the percentage that we have found for samples of dry land wheat, and higher than some exceedingly mealy samples of this variety. We have found, generally, about 13.0 percent of protein for this variety of wheat grown with irrigation.

The experiments of 1913 were not entirely satisfactory to Mr. Bark, so he endeavored to make those of the next year more satisfactory to himself and, for my purposes they are much more conclusive.

An Additional Test at Boise, Idaho, In 1914

The experiments here described were made on six plots of land, each approximately one-tenth of an acre in area. These plots were arranged in two series of three each, the series abutting on one another. One series was not fertilized, the other received an application of well-rotted horse and cow manure at the rate of 15.67 loads to the acre. The land was plowed in November, harrowed and disced in the spring, seeded 2 April, and corrugated 4 April. Wheat practically all up by 25 April. One plot in each series received the same amount of water, i.e., they were paired, one manured and one unmanured. One of these pairs received one acre-foot, one 2 and one 3 acre-feet of water. The manured plots yielded as follows per acre: With 1 acre foot of water, 4,033 pounds of straw and 1,467 pounds of wheat; with 2 acre-feet of water, 4,228 pounds of straw and 1,663 pounds of wheat; with

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3 acre-feet of water, 3,489 pounds of straw and 1,826 pounds of grain. The unmanured plots yielded as follows: One foot of water, 1,713 pounds of straw and 1,000 pounds of wheat; 2 feet of water, 2,183 pounds of straw and 1,144 pounds of wheat; 3 feet of water, 2,511 pounds of straw and 1,266 pounds of wheat. The distribution of the water was as follows: Those plots that received 1 foot of water were irrigated 2 June, 19 June, and 16 July, those that received 2 feet of water were irrigated 21 May, 11 June, 26 June, 8 July and 15 July; those that received 3 feet of water were irrigated 11, 20 and 29 May, 12 and 25 June, 3 and 15 July. The grain was ripe by the 24th or 25th of July, or 114 days from planting. The plots were harvested as soon as ripe and the grain threshed 11 August. The variety used this season was the Marquis. The grain without exception was good. The individual kernels were of good size and well filled, 1,000 kernels from the unmanured plot that received 2 feet of water weighed 33.90 grams, and from the corresponding manured plot 35.77 grams. I judge the latter to be the very best of the six samples. All of the samples contain many half-mealy or mealy berries. No distinction can be made in this respect between the grain grown with or without manure, without a very careful count which, owing to the color of the berries, would be very difficult to make with any high degree of accuracy. If any distinction can be made between the samples in this respect, the second sample given above may be the least affected of the six. This was grown on a manured plot with 2 feet of water. The analyses of these samples including the ash constituents follow:

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SAMPLES OF WHEAT GROWN WITH DIFFERENT QUANTITIES OF WATER, BOISE, IDAHO—CROP 1914

Variety	Water applied Per acre	Manure applied Per acre	Moisture Percent	Ash Percent	Fat Percent	Fiber Percent	Nitrogen Percent	Protein Percent	Starch Percent	Sucrose Percent	Wet Gluten Percent	Dry Gluten Percent	True Gluten Percent	Phosphorus Percent	Potassium Percent
Marquis,	1 foot (1.05)	None	8.833	1.857	2.103	3.185	1.839	10.423	63.198	1.249	26.50	11.37	7.669	0.450	0.406
Marquis,	1 foot (1.07)	15.7 loads manure	8.398	1.804	2.175	3.140	1.853	10.557	61.794	1.507	25.33	10.94	7.381	0.449	0.422
Marquis,	2 feet (1.94)	None	8.790	1.878	2.075	3.120	1.846	10.519	62.820	1.178	27.73	12.44	8.079	0.454	0.401
Marquis,	2 feet (2.01)	15.7 loads manure	8.608	1.943	2.068	3.170	1.897	10.813	63.144	1.249	27.30	11.75	7.864	0.452	0.408
Marquis,	3 feet (2.99)	None	8.608	1.928	2.120	3.062	1.846	10.519	62.406	1.306	27.67	11.83	8.005	0.456	0.422
Marquis,	3 feet (3.05)	15.7 loads manure	8.648	2.009	2.090	3.035	2.047	11.931	61.472	1.346	27.33	11.42	7.904	0.458	0.405

WHEAT GROWN WITH AND WITHOUT MANURE AND WITH DIFFERENT QUANTITIES OF WATER, BOISE, IDAHO

Variety	Water applied per acre	Manure applied per acre	Amid Nitrogen Percent	Albumin Nitrogen Percent	Gliadin Nitrogen Percent	Glutenin Nitrogen Percent	Total Nitrogen Percent
Marquis	1 foot (1.05)	None	0.1223	0.1958	0.6372	0.8831	1.8385
Marquis	1 foot (1.07)	15.7 loads	0.0453	0.1888	0.6975	0.9227	1.8525
Marquis	2 feet (1.94)	None	0.0628	0.1958	0.7014	0.8855	1.8455
Marquis	2 feet (2.01)	15.7 loads	0.0593	0.1958	0.7003	0.9316	1.8970
Marquis	3 feet (2.99)	None	0.0453	0.1818	0.7330	0.8854	1.8455
Marquis	3 feet (3.05)	15.7 loads	0.0523	0.2307	0.7260	1.0375	2.0465

MINERAL CONSTITUENTS OF WHEAT GROWN WITH AND WITHOUT MANURE AND WITH DIFFERENT QUANTITIES OF WATER, BOISE, IDAHO—CROP 1914

Variety	Water applied Per acre	Manure applied Per acre	Sp. gr.	SiO_2	Fe	Mn	Ca	Mg	K	Na	Cl	S	Total P	Inorganic P	Organic P	Total P
Marquis	1 ft. water	None	1.4204	0.032	0.006	0.006	0.038	0.154	0.406	0.027	0.086	0.104	0.455	0.034	0.421	1.839
Marquis	1 ft. water	15.7 loads manure	1.4283	0.028	0.005	0.006	0.043	0.150	0.422	0.035	0.100	0.114	0.447	0.036	0.411	1.853
Marquis	2 ft. water	None	1.4307	0.028	0.007	0.005	0.042	0.156	0.401	0.053	0.089	0.123	0.454	0.040	0.414	1.846
Marquis	2 ft. water	15.7 loads manure	1.4336	0.050	0.006	0.006	0.047	0.156	0.408	0.056	0.072	0.119	0.452	0.036	0.416	1.897
Marquis	3 ft. water	None	1.4193	0.045	0.006	0.005	0.038	0.161	0.422	0.067	0.101	0.124	0.456	0.032	0.424	1.846
Marquis	3 ft. water	15.7 loads manure	1.4173	0.054	0.006	0.005	0.036	0.158	0.405	0.035	0.096	0.078	0.458	0.029	0.429	2.047

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Owing to the prevalence of mealiness in the kernels, mentioned in the last paragraph before the table, we would expect a rather low percentage of crude protein, but, according to our previous observations, we would not expect any noticeable increase in the starch. We have given, among our general samples, three of this variety grown at Fort Collins on fallowed ground, and with one irrigation. These are higher in protein but quite similar, in regard to the starch, to the Idaho samples. The protein in our samples is 13.8, 14.0, and 16.0, while the starch is 59.1, 60.2, and 59.9 percent. Our samples received but one irrigation, about 12 June, which was probably at the rate of 1 foot to the acre, or perhaps less. The Idaho samples received from three to seven applications of water, aggregating from 1 to 3 feet. At the present we will consider the Idaho samples by themselves. The applications of 2 and 3 feet of water increased both the yield of straw and wheat, and the manure effected a further increase. The unmanured plots yielded 1,000, 1,144 and 1,266 pounds of wheat per acre with 1, 2 and 3 feet of water; the manured plots yielded 1.467, 1.663 and 1.826 pounds with the respective applications of water. The effects upon the amounts of straw were relatively the same. From the standpoint of dry matter produced, it is evident that there is an increase due to the more liberal application of water. The manure produced an increase in crop and the application of larger quantities of water produced its own effect, which was slightly enhanced by the influence of the manure. This phase of the question is mentioned merely for the purpose of taking cognizance of the facts in the case and not for the purpose of discussing them. The feature that I want to present is: What, if any, was the effect of the different quantities of water applied upon the composition of the grain? The preceding statements will be deemed as sufficient so far as the crop is concerned.

Experiments of 1914 Give Practically the Same Results as In 1913

These analyses, when compared with one another, do not show any differences in composition which can be attributed to either the water or the manure. By common consent, justified by the facts, we look to the nitrogen content as the key to the solution, but we may in this case take all of the constituents one by one, and we will arrive at the same conclusion, i.e., that there is no variation due to these factors of sufficient size to justify serious consideration. It is true that there is a shadow of difference in the amount of protein present in favor of the produce from the manured plots reaching 1.4 percent in the case of the manured plot that received 3 feet of water. That 15.67 loads, probably not far from 16 tons, of well-rotted manure per acre should have so little, practically no effect upon the composition of the grain, is a little surprising at first sight. The water was applied, as has been stated, at different intervals up to within ten days of full maturity.

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This, as we have learned from the study of the changes of the nitrogen in the plant, would be just about at the beginning of the period of most active transfer of the nitrogen from the plant to be berry. The plots that received 1 foot of water had three irrigations, those that received 2 feet had five, and those that received 3 feet had seven. These latter had an irrigation at intervals of nine or twelve days. The ground must have been quite wet all of the time, as the average amount applied at one time must have been about 5 inches, but the wheats from these plots do not differ in their nitrogen content; the plot that received 1 foot of water in three applications produced wheat containing 10.423 percent of protein and the one that received 3 feet of water in seven applications produced wheat with 10.519 percent protein. Neither the amount of water nor the distribution of it has affected the protein content of the wheat. It might be better to state that both together have produced no effect upon the composition of the wheat. It goes without saying that this wheat was kept growing all the time and never suffered for moisture. The supposition is that the weather was bright and favorable. The element next to nitrogen in its sensitiveness to the relative food supply is probably phosphorus, which rises and falls inversely with the nitrogen; in this series it is uniformly very high, and just as high in the manured plots as in the unmanured ones. Attention is called to this particular feature at this time, for the good reason that I intend to point out that comparatively small amounts of nitrogen in the form of nitrates produce marked effects upon the composition of the wheat.

Results In Colorado and Idaho Identical

The results of these two seasons of experimentations are altogether consistent with the results obtained with our own samples of 1913 and 1914, one a season of high and the other of low quality in our wheat. As these Idaho experiments were carried out in a much more systematic manner than ours, I shall content myself with these and omit ours.

These facts and results apply in answering the question relative to the effects of the distribution of the moisture, raised in discussing the causes for the poor composition of our 1915 crop, in which, after citing the fact that our crops of 1913 and 1915 were grown with practically the same amounts of water, I said: **"This fact relieves me from the necessity of considering the quantity of water used as the cause of these differences, but if it were necessary to do so, I would take the ground that a variation in the amount of water from 12 to 36 inches would not produce these results."**

Water and Manure Affect Volume of Crop, But Do Not Affect Composition

If we admit the samples of Turkey Red grown in Idaho to a place in these series of experiments, we have a range in the water used from

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0.41 foot to 3.28 feet, without discovering that the amount of water *per se*, provided that the plant does not actually suffer for the want of water, has any influence upon the composition of the wheat, or this influence is so small that it is concealed by the influence of the other soil factors. Both the amount of water and the manure had an influence upon the volume of the crop, but no influence upon its composition.

Knowing nothing to the contrary, I assume that the weather was bright and the plants themselves were uniformly dry exteriorly, and grew in sunshine and with good ventilation, that is, there was no lodging and the air circulated freely between the plants. The total rainfall at Boise, Idaho, for May, June, July and August, 1914, was 2.39 inches.

WHY PROTEIN CONTENT IS MOST SIGNIFICANT FACTOR IN THIS STUDY

I have followed others in considering the amount of protein contained in the grain the most significant compound for the purposes I have had in view. This is justified, both by the important part that it plays in the use to which the grain is put, principally bread-making, and also by the fact that it varies greatly in quantity in proportion to the amount present. The starch, which in its total quantity exceeds the protein by four or five times, varies less as a rule than it. The method of determining the nitrogen is, probably, the most accurate one used in the ordinary analysis of the grain, so that it forms the best single analytical criterion for the estimation of the probable quality of the wheat. The other compounds are present in relatively small proportions and small percentage variations may really have great significance in regard to the living processes of the plant, but they are more difficult both to establish and to interpret. A plant physiologist, perhaps, might make out the reasons for, and the significance of the fact that the crude fiber in the Marquis wheat may vary 0.70 percent when grown in different localities. But, considering the difficulties in making this determination a real close one, and the fact that the amount of the fiber which is largely contained in the bran varies but little from 2.8 percent, it would seem, in the main, unwise to give this constituent any prominence. The same may be said of the phosphorus, but not with the same justice, for the determination can be made with an exceedingly high degree of accuracy and though its quantity is small, this quantity can be shown to bear a general relation to the amounts of other substances present in the grain and eventually in the soil. In Ohio Bulletin 221, p. 22, for instance, the author, J. W. Ames, says: **"Phosphorus applied to the soil, showing a deficiency of this element as measured by crop yields, increases the amount of phosphorus in**

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the grain. Associated with this increased amount of phosphorus there is an increased quantity of potassium and a decreased amount of nitrogen." Another conclusion is formulated as follows: "The percentage of nitrogen in the wheat plant varies with the supply at its disposal, and is also influenced to a considerable extent by the supply of phosphorus." p. 23. This observation of Ames is undoubtedly correct, but I have omitted, in the preceding discussion, reference to these facts, preferring to consider the more evident and commonly considered features, though not necessarily the more important ones.

THE EFFECTS OF THE VARIOUS ELEMENTS OF PLANT FOOD UNDER OUR CONDITIONS

Nearly all of our data has been presentel but up to the present time I have given consideration to such subjects as have been forced upon me by the questions arising from the conditions that prevailed in the different seasons. There has been no neglect of the object had in view when we planned the experiments, but the questions presented had to be answered in some manner before we could discuss those which our experiments were made to answer. Without first answering the questions that we have present we could not answer the ones that we wished to discuss, i.e., What are the effects of the respective elements of plant food under our conditions? The answer to this question is necessary in order to approach the primary question of our investigation, to-wit: Why do wheats soften, if they do, under our conditions?

At the present time we can discuss only the questions of composition and physical properties, and if to any degree at all, only incidentally, any matter pertaining to the baking qualities of the flour. Our experiments resolve themselves into three experiments repeated four times with each of three varieties of wheat each year; namely, a check plot and three others, one of which received an application of potassium, one phosphorus and one nitrogen. The fundamental data are, of course, taken to be those furnished by the check plots. In making this choice of arrangements I fully appreciated that it was a purely gratuitous assumption that our check plots would yield normal wheat for our conditions. But this seemed to be a matter of some indifference, for the character of the wheat produced on the plots receiving the individual fertilizer would be like that produced on the check plot or they would be either better or worse, and as we repeated this nine times a year with each of the fertilizers we hoped to find out what effect the individual plant foods produce under our conditions. As has already been pointed out, climatic and pathological conditions intervened which produced very serious results. I have presented these results to the best of my ability and I hope in an entirely unprejudiced manner. It remains for me to present the effects produced by these fertilizers as I believe them to be shown by our data.

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In planning this work, I of course, proceeded on certain assumptions. I firmly believed, and still believe, that the development of unusual amounts of nitrates in our soils in the Arkansas Valley accounted for the deterioration in the quality of the sugar beets between the years of 1898 and 1910. I succeeded in showing that the application of nitrates produced those properties in the sugar beets that constituted the points of inferiority in the deteriorated beets—late ripening, characteristically shaped beets, low sugar content, and juices that produced much molasses and which crystallized with difficulty.

There is no reason for concealment of the fact that I thought it probable that this characteristic of our soil might be in part or wholly responsible for the weakness complained of in our wheat. Any collection of samples of Colorado wheats, taken at random, will make it perfectly evident that some other factor than climate or irrigation is at work in determining the character of the wheat, for samples of the same variety from the same locality vary exceedingly in the color, size, shape and hardness of the kernels, and further, in their protein content.

It is very common to characterize wheat kernels according to their appearance as flinty and mealy. This mealiness is designated in many of our states as yellow-berry. I cannot state that the general complaint of softening referred specifically to the yellow-berry kernels, but rather to a general fact that our flour does not yield enough bread. Nevertheless, I am sure that some millers regard the two terms as indicating the same condition. At the present time I do not intend to present the milling and baking qualities of these wheats, as these constitute distinct problems, though incidental reference to some features of them may be almost unavoidable.

Mealy Kernels Result If Available Nitrogen Is Too Low

There is no question but that this difference in the appearance of the kernels of the same variety corresponds to a difference in composition, a fact recognized, so far as I know, everywhere at the present time. Schindler in "Der Getreidebau" (1909) p. 151, cites P. Holdefleiss as showing in 1900 that such kernels differ by 2.44 percent in protein. We have discussed this condition in regard to its cause in Bulletin 205 and from the physical results alone came the conclusion that this condition in the kernel was to be attributed to the ratio between the available nitrogen and available potassium. If the available nitrogen is too low, mealy berries are produced. In previous pages of this bulletin I have discussed the view put forward by some that this condition is due to the amount of water applied as irrigation, and have given my reasons for rejecting it.

There is one statement in that discussion, however, that deserves further consideration. It is the statement asserting the manner in

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which an excess of water may act in bringing about this mealy condition of wheat, namely, by diluting the nitrates.

Lawes and Gilbert, discussing the effects of rain on the wheat crop, say: **"It has of course long been known that an excess of wet is injurious to the wheat crop, but it is only comparatively recently that one at least of the material causes of the adverse influence has been clearly made out; namely, the great loss of nitrogen carried off by drainage in the form of nitrates."***

I have shown, in Bulletin 208 and again in Bulletin 217, the extent to which the nitrates may be washed out of the soil by an irrigation. Further, it has been stated that the application of 40 pounds of nitrogen per acre applied at the time of planting produced the characteristic effects of the nitrates though an irrigation of 1 acre-foot was applied on 12 June, nearly a month before the plants came into bloom. We have also demonstrated how efficient such an irrigation is in removing the nitrates from the upper portions of the soil, and further, the rate at which they are re-established in our soil, knowing very well, that this rate depends upon the nitrifying efficiency of the soil with which we are dealing.

VARIATION OF NITRIC-NITROGEN IN SOIL AFFECTS MEALINESS OR STARCHINESS OF CROP

There is another way of looking for the cause of this mealiness and flintiness in the kernels; this is to ascertain whether the characteristic differences in the composition of these kernels can be produced at will by the fertilizers applied. If so, the cause will be more firmly established. We have given, in the table "The Composition of Yellow-berry and Flinty Kernels Grown Under Identical Conditions", fifteen pairs of analyses made on kernels of these characters selected from the same sample of grain. We find that the flinty berries are uniformly higher in total nitrogen, true gluten, gliadin and glutenin than the yellow-berry kernels. We find the same difference, only in a slightly greater degree, between the wheats grown with the application of nitrates and the averages for all the other samples. In 1913 we have, for the average of all the samples grown without the application of nitrates, 12.53 percent protein and 7.55 percent of true gluten, for the samples grown with nitrates 14.17 percent protein and 9.11 percent true gluten; in 1914 we have 9.42 percent protein and 6.91 percent true gluten for the samples grown without and 11.61 percent protein and 8.67 percent true gluten for those grown with the application of the nitrates. In 1915 we have 8.95 percent protein and 5.67 percent true gluten for the samples grown without and 11.50 percent protein and

* "Our Climate and our Wheat Crops," Rothamsted Memoirs, V.

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7.87 percent true gluten for those grown with the application of the nitrates. We have, then, a characteristic distinction in the composition of these wheats which is independent of the weather conditions, at least within the extent that they varied in these three seasons, and also independent of the pathological effects produced by the rust. I have explained that I attribute the depression of the average percentage of protein from 12.53 in 1913 to 8.95 in 1915 to the direct influence of the rust and do not believe that the weather has much direct influence upon it. Of course, I do not assert that it had no influence, but I think that this influence was negligible compared with that of the rust. The effect of the rust was certainly as severe in the case of the grain produced with the application of nitrates as in that of the others, in fact it was certainly much more severe if the effect is proportional to the abundance of the parasite on the plant. The differences given for the protein in the wheats grown with and without nitrates are 1.64 percent in 1913, 2.22 in 1914, and 2.55 in 1915. These figures represent the crop. There were almost no mealy berries in the samples grown with the nitrate, but in the other samples there were a great many, up to 96 percent, mealy or half-mealy berries. The differences found in the crops, taken in mass, are about the same as those found for the flinty and mealy berries selected out of the same samples. The table given to show this difference shows that the Kubanka, in which a much sharper division of the flinty and mealy kernels is possible than in the case of the Fife, presents a variation of this difference, ranging from 1.9 to 2.7 percent. We produced the flintiness in one crop, and with it the increase of nitrogen, by the application of sodic nitrate or nitric-nitrogen. The same difference is found in the flinty kernels selected from the produce of the other plots. I attribute it to the same cause. If it be asked whether I assert that the nitric-nitrogen varies enough from place to place in a piece of land to produce this result, I answer yes. This is the explanation that I offer for the facts presented by Prof. Montgomery in Bulletin 269 of the Bureau of Plant Industry, and is my answer to the questions which he formulates as follows: **"Why should one plant growing under practically the same enviroment as another, collect from the soil two or three times as much nitrogen?"** Prof. Montgomery continues, giving answer to suggested, but unexpressed questions: **"The three plants are from the same mother growing in the same centgener probably less than two feet apart, yet the actual grams of nitrogen gathered differ more than 100 percent. This difference is not inherited as these plants rarely transmit this qualiy."** The uniformity of enviroment, the fertility of the soil being included, was only apparent. The temperature, moisture, winds, sunshine may have been identical, but not the supply of available nitrogen. The witnesses to this fact are the percentages of nitrogen in the mature wheat. This is in perfect accord with the facts that we find pertaining to the

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distribution of both total and nitric-nitrogen within limited areas. We selected 150 square feet, forming an area 5 x 30 feet, and took from the middle of each foot a core 2 inches in diameter to a depth of 1 foot, and determined the total and nitric-nitrogen in each sample. We found but few samples from adjacent square feet that did not vary both in the total and nitric-nitrogen, sometimes by significant quantities. We found, for instance, in two contiguous square feet, total nitrogeh 0.13600 and 0.14552 percent, and nitric-nitrogen 8.33 and 14.18 p. p. m. We found as low as 6.02 p. p. m. nitric-nitrogen in 1 square foot. This gives us a difference of 5.83 p. p. m. nitric-nitrogen in contiguous areas, 1 foot square, and a maximum range of 8.16 parts in 150 square feet. I made the statement, just above, that the total and nitric-nitrogen varied by significant quantities. In using this expression I am not begging the question by using general terms. The fact is that I do not know, and no one else, so far as has come to my knowledge, has even made an attempt to determine, how small a quantity of nitric-nitrogen in the soil may affect either the quantity or quality of the wheat produced. But we have shown the effects of 10 p. p. m. of nitric-nitrogen, reckoned on the surface-foot, applied to the wheat at planting time. That a less quantity will affect the growth and composition of the crop is very probable, for this quantity was sufficient to produce plants showing the effects of over-feeding in a very marked degree. This amount produced lodging to the very line to which it was applied, it produced broad-leaved, green plants with weak lower nodes, small, often shrunken, kernels and increased the protein in the grain by approximately 2 percent in every case of its application, excepting one or two, in the three years that we have been conducting these experiments. Twice the amount of nitric-nitrogen, 20 p. p. m., produced a greater effect by about 0.7 percent and three times the amount, 30 p. p. m., produced a further increase of about the same amount in the average composition of the crops. The variations, then, in the amounts of nitric-nitrogen within an area of 150 square feet, being about 8 p. p. m., are sufficient to account for the variations observed by Prof. Montgomery, and also to account for the occurrence of flinty and starchy kernels in the same lot or sample of wheat.

MANURE HAS NO EFFECT ON AMOUNT OF YELLOW-BERRY OR COMPOSITION OF GRAIN

There is one feature made evident by the Marquis samples grown at Boise, Idaho, in 1914, which requires discussion in this connection. I have pointed out that the application of water in quantities varying from 1 to 3 feet made no difference in the composition of the wheat, and had no effect upon the prevalence of the yellow-berry in the samples. At the same time, as will not escape the notice of some, the ap-

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plication of 15.67 loads of well-rotted manure produced no effect either on the amount of the yellow-berry, or upon the composition of the wheat in two out of the three cases. The third case, standing against the two others, and being moderate in amount, is not sufficient to preclude almost any other explanation.

It is not a new observation that the application of farmyard manure may increase the yield of both the straw and grain without affecting the composition of the latter. Ritthausen and Dr. R. Pott,* after stating that it has been frequently observed that the liberal application of nitrogenous manures generally increases the protein in the mass of the plant produced, and adding that this has been proven beyond doubt, for root crops, potatoes, beets, etc., continue: "The results that have been obtained in growing grains (Samen) have proved much less definite. While the older investigations of Hermbstaedt† and Boussingault‡ show that wheat and rye seed increase notably in their protein content on the liberal manuring of the soil with substances rich in nitrogen, those of John in Hohenheim and further those instituted by Lawes and Gilbert yield contrary results, according to which the content of these substances (protein) in the seeds is more or less depressed, and A. Mueller finds in the analyses of barley, grown after different manuring, no essential difference in the composition.§

"It accordingly appears doubtful that manuring with nitrogenous substances exercises a definite influence upon the protein content of the seed."‖

Ritthausen and Pott used sodic nitrate and ammonic sulphate as nitrogenous manures in their experiments and found an increase of 32.0 percent in the amount of nitrogen in the harvested grain. They take the average percentage of nitrogen present in the unfertilized plots as 100 and the average found for those fertilized with nitrogen was 132.

Some of these experiments were made eighty-odd years ago, but we have the same results now as then. The effect of farmyard manure is at best doubtful, so far as the composition is concerned, but not at all in regard to the crop. The data given by Kosutany¶ show that farmyard manure does not always increase the nitrogen contained in the berry. The increase shown in his two pairs of analyses is 0.31 and 1.69 percent of protein respectively. The latter difference may have been due to the effects of the manure, but Ritthausen and Pott obtained an increase of 5.19 percent of protein by the use of nitrogen as sodic nitrate or ammonic sulphate.

* Schweigger Journ., 46-278-285; Erdmann Journ. fuer tech u oekonon, Chemie XLL, 1-53 (1832). See also Wolff die chemischen.

† Boussingault, die Landwirthschaft, 1. p. 290-291

§ Stockhardt Zeitschrift, fuer deutche Landwirthe (1855) p. 172-174.

‡ H. Ritthausen and Dr. R. Pott. Die landwirthschaftlichen Versuchs-Stationen Vol. XVI. p 385, Author's translation.

‖ Kosutany Der ungarische Weizen und das ungarische Mehl pp. 171-172.

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NITRIC-NITROGEN INCREASES NITROGEN CONTENT AND PRODUCES FLINTY KERNEL

Our results in 1913, a favorable year, showed a gain from 0.57 to 3.36 percent of protein, but there was in every case in which the sodic nitrate was applied a greater or smaller increase. Similar results were obtained in 1914 and 1915, but the maximum differences were a little greater. The different results obtained with farmyard manure, amounting in some experiments to contradictions, may be due to the form in which the nitrogen is present, or to the nitrifying efficiency of the soil. It appears to be certain that nitric-nitrogen, or easily nitrifiable ammonic nitrogen, increases the nitrogen content of the grain and produces flinty berries; this is not the case with farmyard manure, or if farmyard manure ever produces flinty berries with an increase in the nitrogen content, it is not uniform in its action, for it certainly does not always do it, while the nitric-nitrogen does.

The statements previously made, regarding the composition of flinty and yellow-berry wheats selected out of the same samples, and concerning the composition of flinty wheat grown with the application of nitric-nitrogen, and yellow-berry wheat grown with the application of potassium, justify me in making the following statements without going into the details of many analyses. The application of nitric-nitrogen produces flinty kernels, an increase of protein, amounting in some cases, to more than 2.0 percent, and a corresponding increase in the true gluten. The same relation exists between the starch present in the flinty wheat produced by the nitric-nitrogen and in the wheat grown with the application of potassium as exists between the percentages of this substance in flinty and mealy kernels sorted out of the same sample. In regard to the mineral constituents, there is usually a little more potassium in the mealy samples than in the flinty, especially in normally developed berries. The phosphorus is depressed by the application of nitrogen, to which statement we have found but few exceptions; on the other hand, it cannot be said that potassium has increased it. This suppression of phosphorus is exhibited, not only by our samples grown with the application of nitric nitrogen, but also in samples of flinty wheats from other sections when compared with yellow-berry wheat from the same section. This statement applies to the crop and is not based on selected kernels. The samples here referred to were grown in the immediate neighborhood of one another and on the same type of soil, so the questions of climate and type of soil are eliminated. The flinty wheat, in this case, contained 0.114 percent less phosphorus than the yellow-berry sample. The flinty sample was grown on land so rich in nitrate that an ordinary aqueous extract of the soil reacted strongly for nitric acid with ferrous sulphate and sulphuric acid. The yellow-berry crop in this case contained 50.0 percent more phosphorus

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than the flinty crop. These two crops, grown with irrigation, show in a very marked manner the composition characteristic of the two classes of wheat. Our dry-land wheats are usually winter-wheats, but they show this difference in physical properties and these characteristics in their composition, so it is not a question of water supply. Another dry land sample of Turkey Red presents as marked a case of yellow-berry as any sample of this wheat in my possession, and contains only 9.04 percent of protein, while the other samples of yellow-berry wheat of the same variety, grown with irrigation, contained 9.65 and 10.05 percent protein. Irrigated wheat of the same variety, grown in the same section of country as the latter two, and from the same lot of seed, contained 13.21 percent of protein, but it was all flinty. The mills willingly accepted this sample, but objected to the former. These samples are good illustrations of my previous statement that the phosphorus is usually lower in the flinty wheats, in which the flintiness is directly due to the influence of nitric-nitrogen. We have in the last two yellow-berry wheats, 0.309 and 0.345 percent phosphorus; the flinty wheat, which undoubtedly owed its flintiness to nitrates in the soil, contained 0.231 percent. They also serve to illustrate the other statement that the potassium is usually a shade higher in the yellow-berry wheats than in the flinty ones, in the yellow-berry samples we have 0.539 and 0.561 percent potassium, in the flinty samples we have 0.485 percent. The statement previously made was based upon results with spring-wheats. These Turkey Red wheats were grown with a water supply ranging from 6 inches of rainfall to 6 inches of rainfall plus one good irrigation during the season in which the wheat ripened.

We have just seen that a scarcity of water does not prevent yellow-berry, which is used in this connection as indicative of composition, as much as to indicate a physical condition. We have also shown that much water does not produce it, and further does not affect the composition of the wheat under ordinary conditions. I am at the present time satisfied that under some conditions, a too liberal supply of water would produce changes in the composition of the wheat, but for all ordinary conditions I let the above statement stand unmodified. I will repeat some data already given to show to how great an extent I am justified in making this statement. I have two samples of spring-wheat, one of Defiance, the other of Red Fife, which were grown without irrigation and with a rainfall of 6.77 inches. These samples contained 13.92 and 15.20 percent protein respectively. A sample of the latter variety grown with irrigation and grown close to the last one given, within 150 feet, contained 17.14 percent protein, while the seed from which the Defiance sample was produced, grown with irrigation, contained 14.92 percent of protein. A very much fairer test of the effects of the amount of water upon the prevalence of yellow-berry

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and the composition of wheat is the Marquis wheat grown at Boise, Idaho, of which I will give in this place only three samples; the one grown with 1 foot of water contained 10.423 percent, the one grown with 2 feet of water contained 10.557 percent and the one grown with 3 feet of water contained 10.519 percent of protein. The other features of their composition were just as close to one another as are the percentages of protein. The other three samples in this series were heavily manured with farmyard manure and two of them are identical with the three already given. The third one differs slightly in its percentages of crude protein, but is the same in its true gluten, so that five of the six samples are identical in their composition, and the sixth one is at most uncertain. These samples are all strongly affected with yellow-berry and are very high in both phosphorus and potassium, but the potassium is not quite so high as in the Dicklow spring-wheat, which is very mealy and very rich in potassium. The averages for the Marquis are, potassium 0.416, and phosphorus 0.454, for the Dicklow, the potassium is 0.506 percent.

The question may be raised whether 1 foot of water may not suffice to produce the maximum amount of change in the composition of the wheat. In this case the results obtained by the addition of the second and third foot of water would be wholly inconclusive. Again, it may be asked whether the distribution of the water was such as to make the test of the different quantities of the water conclusive. I think that the data given affords an affirmative answer to the latter and to the former also. But I may give the results obtained with a plot of Marquis wheat at this place. This plot was fallowed ground. It received one irrigation, 1 foot or less of water. The yellow-berry was less than 15 percent, protein 15.998 percent and phosphorus 0.374 percent. The Boise samples, manured and not manured, that received 1 foot of water were practically 100 percent mealy and half-mealy, contained 10.42 and 10.56 percent protein and 0.450 and 0.449 percent phosphorus respectively. The weather conditions were equally favorable in the two cases.

In addition to this, the fact that we can grow, on the same tract of land, using the same quantity of water, either flinty or starchy crops with their characteristic composition as we will, proves that flintiness and starchiness are not products of the weather, or dependent upon the water supply in quantities up to 36 inches, we may say 42 inches, for we should add six inches of rainfall.

We have now discussed the effects of potassium and nitrogen without separating them or specially designating them. We have also considered fully the effects of water applied as irrigating water. We have further considered the effects of farmyard manure, which has the effects of a potassic rather than those of a nitrate manure. Further

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we have suggested that frequent light rains and heavy dews may have a different action on the plant than many times their volume applied to the soil. We have shown in Bulletin 217 that the transfer of nitrogen from the plant to the head is practically inhibited by an attack of rust. We have shown in this bulletin that the protein content of the grain is greatly depressed by such an attack. We have also pointed out that the composition of the shriveled wheat is not different from plumper wheat produced under similiar conditions, and that the protein and starch are transferred to the kernel at the same time. Further, that the period of rapid transfer is brief; in 1913 it apparently extended over a period of five days. Further, that in 1915 this transfer did not take place, not directly because of the weather, but because of the rust, *Puccinia graminis*, which attacked the plants severely at this time. We have given the gluten, especially the true gluten, to show its intimate relation to the crude protein, also the phosphorus and potassium in all the samples to show their dependence upon and relation to the composition of the wheats. We have said nothing about the effects of phosphorus for the reason that in our soils, under our conditions, it has failed to produce such effects that we believe can be interpreted; in other words, its effects upon the growth of the plant, the ripening of the grain, and the character of the wheat produced have not been decided enough, that is, they have not been of sufficient magnitude, to justify us in entertaining even tentative judgments relative to them, in fact, we are compelled to doubt whether this element has exerted any influence at all. We have carefully avoided, and even disclaimed, any opinion relative to the milling and baking qualities of these wheats, though we have found it convenient to give the gluten for the purpose stated above, and have given the gliadin, glutenin, etc., for future reference. In regard to the hardness and softness of the varieties experimented with, we have given their crushing strength in considerable fullness. The statement of these results is possibly due the reader, but he must put his own value on them. I cannot see that any useful fact has been established by the data acquired.

We have shown in grams the difference in the crushing strength of the flinty and mealy berries as given by this method. This difference varies from 3,000 to 5,000 grams, but it is doubtful whether this corresponds to the differences in composition or quality of the wheat. The suggestive fact that I have in mind is this: The Kubanka, as grown on our land with irrigation, is a hard wheat, i.e., has a high crushing strength; the averages obtained vary from 17,000 to 19,000 grams. The Red Fife, for samples grown in the same season on adjacent plots, yields a crushing strength of 10,000 grams. The Kubanka was lower in its protein content than the Red Fife. This difference does correspond to a difference in the deportment of the two wheats

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in the mill, the Kubanka working very unsatisfactorily in a short reduction. This is due to the difference in the manner of breaking into gritty meal. The miller may know how to eliminate this difference by varying his tempering process. We have offered no explanation for the difference in the deportment of the Red Fife and Kubanka on drying at 100 degrees C. for seven hours, the crushing strength of the one being regularly increased, and that of the other decreased rather than increased, for the sufficient reason that I know of no reason to offer. The kernels are certainly effectively dried on being heated at 100 degrees C., under a pressure of not more than 75 mm. for seven hours.

SUMMARY

Our conclusions in the matter are as follows:

That the wheat plant is much more easily influenced in the character of its product, seed, by the soil fertility than we have been taught to believe.

That the individual elements of plant food exercise specific influences on the composition of the grain produced.

That nitrogen in the form of nitric-nitrogen in the soil affects the growth of the plant, increasing the nitrogen in both the plant and the seed.

That nitric-nitrogen influences both the composition and the character of the grain, producing in the latter respect the characteristic designated as "hard" wheat, i.e., small, flinty, translucent, dark-colored berries; relatively rich in nitrogen.

That these characteristics have a deeper significance in the plant metabolism than the production of an increase of a few tenths of one percent in the nitrogen content of the berry.

That the mineral constituents contained in the berry are influenced by the amount of nitric-nitrogen available to the plant.

That the mineral constituents of the plant are also influenced by the amount of nitric-nitrogen available to the plant, but to a different extent and not necessarily in the same direction as in the berry.

That the nitric-nitrogen produces a soft, weak straw, causing lodging, both by producing a heavy growth of leaves and an elongation of the upper portions of the plant, and by causing a weakness in the lower nodes of the plant.

That nitric-nitrogen greatly increases the susceptibility of the plants to the attack of the rust fungus, probably by furnishing a better

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nutrient and also because of the softness characteristic of such plants, which is probably due to the weakness of the cell walls themselves.

That organic nitrogen in farmyard manure does not produce these results, except in the measure that it is converted into nitric-nitrogen, the rate of which process depends upon the nitrifying efficiency of the individual soil.

That our results do not show that potassium has increased the starch; neither do they show that it has had any positive effect on the quantity of this substance formed.

That potassium has a tendency to suppress the nitrogen content of the berry.

That potassium suppresses the nitrogen in the plant throughout its growing period, particularly in the stems and leaves, but does not appear to suppress it in the head.

That potassium, under our conditions, produces an effect upon the development of the plant as shown by the larger size of the plants at a certain stage of development, but the plants on the other plots attain the same degree of development a few days later, eliminating this difference.

That potassium increases the condition designated as yellow-berry.

That phosphorus under our conditions has produced so little effect that no interpretation is possible.

That the phosphorus in the berry is depressed by nitric-nitrogen but is not affected by potassium.

That manganese is uniformly present.

That the amount of water applied as irrigating water may increase the crop, but has so good as no effect upon the composition of the crop produced.

That the leaching effect of irrigating water on the nitrates in the soil is not sufficient to affect the nitrogen content of our wheat, if first applied when the plants are two months old, or two months after the application of the nitrates.

That frequent light rains, when associated with heavy dews, produce different effects on the plant from those produced by irrigating water applied to the soil.

That the time of the rainfall and the weather conditions succeeding, are the most important factors in determining the effects of rain upon the wheat.

That the importance of these conditions is an indirect, rather than a direct one, depending upon the development of rust or its failure to develop.

That there is a period just before the maturing of the plant, when, under favorable conditions, the plant transfers its substance to the berries.

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That the effect of rust is practically to inhibit this transfer.

That, for the production of the best wheat, there exists an optimum ratio between the nitric-nitrogen and available potassium in the soil.

That, if the potassium predominates, yellow-berry is produced.

That, if nitric-nitrogen predominates, soft, weak plants, small, flinty, and often shrunken berries result.

That, so far as the crushing strength is a proper criterion whereby to judge, our wheats range from semi-hard to hard.

That, so far as composition is concerned, our wheats, produced under normal conditions, i.e., when the plants are free from rust, stand well above the average.

That our soil varies in character to such an extent that there is no general average composition of the wheat produced that can be considered characteristic.

That our climatic conditions are so favorable that differences in composition are, for the most part, attributable to other immediate causes.

That rust causes a very marked depression in the protein content of the wheat, even if the crop is well advanced at the time that the rust attacks the plants.

That rust increases the percentage of crude fiber in the wheat by preventing the filling out of the berries.

That the effects of the fertilizer upon the composition of the wheat and the production of flinty berries, or the increase in the yellow-berry, are not eliminated or concealed by the unfavorable conditions that we had in 1915.

That, on the other hand, the effects of the nitric-nitrogen in increasing the protein content of the wheat was rather emphasized thereby.

That, in 1915, we have shown three classes of effects in the plants, those due to fertilizers or soil, those due to weather and those due to rust.

That of these, those due to rust were by far the most marked and were prejudicial in their character.

That the effect of rust on the grain is to prevent the transfer of the filling material to the berries.

That the shrunken berries due to this cause are not high in protein.

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That small berries sifted out of normally developed crops average a little lower in protein than the large berries.

That fixation proceeds in our soil rapidly enough to furnish a sufficient amount of nitrogen to become an important factor in our problems.

That nitrification proceeds rapidly enough to more than quintuple in five months, the amount of this form of nitrogen in the soil at harvest time. The actual increase was from the equivalent of 43.2 to that of 232.7 pounds of sodic nitrate from August to December, 1915.

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APPENDIX

The analytical methods followed in the work presented in this bulletin differ in some respects from those given in our manuals. This is true to such an extent that I feel it incumbent upon me to give my methods, in justice to myself, and in order that others may prove the work presented, if they wish to do so, by the same methods that I have used.

The preparation of the ash of either the wheat straw or wheat kernels, involves the loss of important elements, phosphorus, sulfur and chlorin, therefore it seemed desirable to avoid this tedious work and the losses.

I believe that Leavitt and LeClerc were the first to call attention to the material loss of phosphorus in incinerating wheat kernels *. My own experience has taught me that the loss of phosphorus due to volatilization renders it almost impossible to make duplicate phosphorus determinations by incineration that agree reasonably well no matter at how low a temperature one may char the wheat.

The loss of phosphorus during the burning of the straw is much more marked. It is impossible, under the joint action of the silica and carbon to expel the phosphorus so completely that only traces of it, a few thousandths of one percent, remain. The determinations not given in the following notes were made by the usual conventional methods, and are therefore omitted.

THE DETERMINATIONS OF IRON, CALCIUM, MAGNESIUM AND THE ALKALIS

These determinations were effected as follows: One or more portions of 25 grams of wheat were treated with concentrated nitric acid in separate portions of 15 to 20 c.c. The mass foams strongly and, if too much nitric acid be added at one time, one is apt to lose the portion, unless an unduly large dish be used. I used a 4-inch silica dish. The whole was evaporated down to a gummy mass before the addition of the next portion of acid. When 50 c.c. had been added, the residue was heated for a while in a hot-air oven, though this is not necessary, and then charred over a free flame and finally put into the muffle. Most of the carbon was burned out. The mass, still containing carbon, was treated with *aqua regia*, the solution evaporated to dryness, the residue treated with hydrochloric acid and filtered. The filter containing the residual carbon and silica was returned to the dish and burned and the residue treated as before. The united filtrates contained all of the bases as phosphates. The silica, together with any crease-dirt, consisting of fine sand, remained on the filter. The total silica and crease-dirt was so small in quantity that no attempt was made to separate them. An examination, however, with an ordinary pocket lens, suffices to show the presence of sand grains.

* Journal Am. Chem. Soc. Vol. 30, pp. 391-394.

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The only objection against the use of silica dishes was the fact that small flakes sometimes broke loose and were weighed as silica. The amount of silica this adds to that of the wheat is extremely small and is usually negligible.

The iron, calcium and magnesium were precipitated as phosphates. The iron was weighed as phosphate, the calcium as oxid and the magnesium as pyrophosphate.

The alkalis remained in the filtrate from the precipitate of the phosphates of iron, lime and magnesia. The filtrate was concentrated, and if still alkaline, was acidulated with hydrochloric acid. An excess of ferric chlorid was added and then ammonia in excess to throw down the ferric oxid and with it the phosphoric acid. The precipitate was filtered off, washed, dissolved in hydrochloric acid and reprecipitated. The united filtrates contain the alkalis as chlorids. The procedure from this on was as usual.

The calcic oxid obtained in the above manner is always slightly brown, due to the presence of manganese. It is very probable that the magnesia is also always contaminated in a slight degree.

The chlorin was determined in a separate portion of 10 grams or more.

The portion of wheat taken was dissolved in a mixture of nitric acid and argentic nitrate. When the wheat was completely dissolved and only a white flocculent precipitate remained, water was added, which materially increased the precipitate. This precipitate contained the whole of the chlorin as silver chlorid or otherwise. It was filtered off, washed in part (washing is not necessary when sucked sufficiently dry by the pump), the mass impregnated with a mixture of potassic nitrate and sodic carbonate, transfered while still moist to a nickel dish containing two or three grams of the deflagrating mixture on which the fully opened filter was placed, covered lightly with the mixture and the whole heated until the mass was completely fused. The amount of the deflagrating mixture used was from five to seven grams. The fused mass was dissolved in water and the usual method for the determination of chlorin followed. The fusion is so quickly made that chlorin, if present in the gas, can cause no appreciable error in the results.

The phosphorus was also determined in a separate ten-gram portion.

The wheat was dissolved in concentrated nitric acid and one and a half grams of magnesic oxid added. The whole was evaporated to a brown gummy mass and ignited. The amount of magnesia added is not sufficient to cause the complete combustion of the organic matter, but the mass burns without deflagration. The cooled and partly white mass was treated with dilute nitric acid, or wet with water, and concentrated acid added, evaporated again, and the combustion completed. The magnesic oxid containing the phosphate was dissolved in nitric acid and evaporated with sulfuric acid to separate silicic acid and the phosphoric acid precipitated as molybdate, and finally weighed as magnesic pyrophosphate.

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The sulfur was determined in the same manner as the phosphorus, except that ordinary gas could not be used, either in evaporating or igniting. I used electricity for the former and gasolene for the latter purpose. The magnesic oxid was dissolved in hydrochloric acid. If the magnesic oxid be heated in the muffle, care must be exercised that it does not attain too high a temperature or a loss of sulfuric acid may occur.

The manganese was determined colorometrically. The wheat was destroyed by nitric acid as in the other instances. The combustion was completed in the muffle, the residue taken up with sulfuric acid and filtered. Any carbon that had escaped combustion was burned off and the residue dissolved in sulfuric acid and added to the first filtrate. The solution contained about 5.0 percent of sulfuric acid. A few milligrams of silver sulfate were added as a catalytic agent. A few grams of ammonic presulfate were then added and the solution heated in a boiling water bath so long as the color deepened.

THE ANALYSIS OF WHEAT PLANTS AND WHEAT STRAW

The analyses of these substances present some difficulties. To determine the ash, I took 10 grams of the ground straw or plant, charred thoroughly and extracted three times with boiling water, then burned out the carbon as completely as possible and extracted again with water as thoroughly as possible. The residue was ignited and weighed as insoluble ash. This portion is seldom white and an examination under the microscope shows the siliceous outlines of the cells inclosing particles of carbon. The water-soluble portion of the ash contains from 25 to 30 percent of its weight of silicic acid. The terms soluble and insoluble ash mean but little in this case. Their sum gives the total ash, less the phosphorus, which in this process may be so good as wholly lost by volatilization. Hydrochloric acid will extract from the insoluble ash obtained in this way about 0.1 percent of the weight of the straw.

For the analysis proper, I took 100 grams of the ground straw and proceeded as above, except that I extracted the charred mass with hydrochloric acid, as it extracts less coloring matter than water. The charred and extracted mass was pulverized, the carbon burned out as far as possible and the residue again extracted with hydrochloric acid. This residue was ignited and considered as pure silica, though it was not white. The hydrochloric acid extracts were evaporated to dryness to separate silicic acid that had gone into solution. The weight of this was added to the insoluble silica and their sum was considered as total silica. The hydrochloric acid solution was made up to 250 c.c. An aliquot part, from 60 to 100 c.c. according to the quantity of soluble ash found in the sample, was taken for further manipulation. A few cubic centimeters of a ten-percent solution of ammonic phosphate were added and the bases precipitated by the addition of ammonia, to which a little ammonic sulfid was added to carry down traces of manganese and, possibly, zinc. The manganese and zinc were present in such small amounts that no further attention was paid to them at this time.

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The separation of the bases and the determination of the alkalis were effected just as in the case of the wheat.

Phosphorus

I took 25 grams of finely ground straw, disintegrated thoroughly with concentrated nitric acid, added 1½ to 2 grams magnesic oxid, evaporated down, and finally heated to introduce the combustion. The residue was not white, but contained much unburned organic matter. Nitric acid was added and the previous operation repeated. The residue, if still too dark, was burned white in the muffle. The thoroughly burned mass was dissolved in nitric acid, a few cubic centimeters of concentrated sulfuric acid added and evaporated, at last, on the sand-bath till the sulfuric acid fumes began to escape, the dish was then placed in a hot-air oven and kept at 160° or higher to separate the silicic acid. The phosphoric acid was separated from this solution with the usual precautions by ammonic molybdate and eventually weighed as magnesic pyrophosphate.

As the silicic acid may give some trouble, this may be removed by digesting the disintegrated straw with 10 to 15 c.c. of strong hydrofluoric acid before the addition of the magnesic oxid.

Sulfur was determined in essentially the same manner as the phosphorus, except that gas cannot be used unless free from sulfur, and the magnesic oxid, which must not be heated too strongly, was taken up with hydrochloric acid and evaporated to separate silicic acid.

The manganese in the straw was determined in ten-gram portions in the same manner as in the wheat, except that to the thoroughly disintegrated mass was added a few c.c., 5 or 6, of concentrated hydrofluoric acid to remove the silica; the mass was then heated for 10 minutes, when I added 5 c.c. concentrated sulfuric acid and continued the evaporation, heating at last over the free flame. The residual mass of carbon usually burned out readily in the muffle.

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The Agricultural Experiment Station
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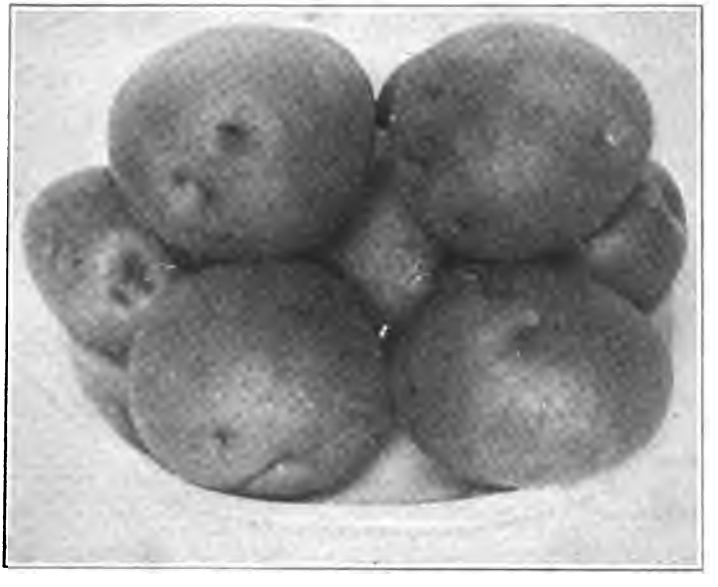
POTATO GROWING IN COLORADO

BY
E. P. SANDSTEN



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POTATO GROWING IN COLORADO

By E. P. SANDSTEN

FOREWORD

The Horticultural Department has received numerous requests for information on the various phases of potato growing in the State. These inquiries cannot be answered fully nor adequately in personal letters, as the subject covers too extensive a field. To answer these inquiries and to furnish reliable information upon the fundamental problems of the grower, this bulletin is written.

While the information contained within is fundamentally correct for the State as a whole, local peculiarities in soil, situation, and climate may necessitate modifications in details, and the grower must meet these modifications as they occur.

The soil and climatic conditions of Colorado are admirably adapted for the growing of high quality potatoes. The development of the industry has not measured up to the possibilities. The present acreage devoted to potatoes is less than it was five years ago. This is particularly true in the Greeley district where diseases have been destructive. With better methods of farming, especially along the line of rotation, and with better seed, the outlook for the future is very encouraging. The acreage devoted to this crop in the State has varied from year to year, generally with the prices obtained. The State may be roughly divided into two general sections known as the Eastern Slope and the Western Slope with the Inter-Mountain Valleys. On the Eastern Slope the most prominent region is the Greeley district in Weld County. The acreage in this section has varied from 6,000 to 20,000 acres annually. The varities grown are the Pearl and the Rural. These are late standard white potatoes, and have proven well adapted to the conditions in this section.

The Western Slope and the inter-mountain valleys produce a very high quality of potatoes. and these general sections bid fair to become the best potato producing regions of the United States. The soil, taken as a type, is a mellow, sandy loam which permits perfect root development, and offers no resistance to the normal growth and expansion of the tubers. With a perfect system of rotation and the plowing under of clover or alfalfa, the vigor and yield of the plants can be not only maintained, but also enormously increased. The principal varieties grown here are the Russet Burbank, Rural, Peoples, Cobbler, and Downing. In the high mountain

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valleys, the Peachblow is grown to perfection, and in the San Luis Valley, Barklay's Prolific or Brown Beauty is extensively grown.

The total acreage devoted to potatoes in Colorado in 1916, was, in round numbers, 29,000, somewhat less than in 1915. The U. S. Census has in the past credited the State with as high as 70,000 acres. If these figures are correct, they show a heavy decline in the total acreage, but we are inclined to believe that the estimates were excessive to begin with.

Present indications point to a revival in potato growing, due to a better understanding of the fundamental requirements of the crop. While the acreage devoted to potatoes is less than formerly, the yield per acre is higher and the net returns to the grower, larger.

SOIL AND CLIMATIC REQUIREMENTS

The potato is naturally a North Temperate crop. The highest yield, as well as the highest quality, is obtained in the northern states and in the cool high valleys in the Mountain States. In warm climates, the potatoes suffer greatly from the summer heat and seem to be unable to produce a satisfactory crop. When grown in the South the crop must be matured before the warm summer weather sets in, and the later crop may be planted in the autumn, maturing during the fall and early winter months.

There is at least one native species of potato found in southwestern Colorado around an altitude of from 6,000 to 8,000 feet, showing conclusively that the mountain sections of Colorado are naturally better suited for the growing of this crop than are the plains sections where the summers are usually hot, and where the plants are subject to diseases occurring in these soils.

The Greeley district has been an exception to the general failure of growing potatoes on the plains, and here potato growing has been carried on ever since the district was first settled, with uniform success, up to within the last four or five years. During the last five years, considerable trouble has been experienced from the presence of diseases, which have caused great losses to the growers. The season of 1915 was very favorable to potato growing, and a normal crop was obtained. Whether this favorable turn in the industry is permanent or not, only the future can tell.

The mountain sections of the State have large acreages in mountain valleys and mesas which have ideal soil and climatic conditions for the highest development of the plant, and these areas should develop into typical potato growing sections, both for the production of seed for the Southern states, and also for high grade market potatoes. Political economy should teach our farmers to

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grow those crops that are best adapted to a given section, and not endeavor to grow them where the conditions are unfavorable.

The failure in growing potatoes on the Eastern plains is due to several causes: First, the soil is too heavy and puddles badly under irrigation. This puddling and subsequent baking of the soil prevents proper aeration of the soil and prevents the normal development of tubers. Second, the day temperature during the summer months is generally too high and imparts a correspondingly high temperature to the soil. Third, potato diseases, due to unfavorable temperature and soil conditions are very prevalent and destructive. On the lighter soil, and in long rotation with alfalfa, potatoes may be grown. On virgin soil and in rotation with grain crops, potato growing should not be attempted.

POTATOES AS A CROP IN FARM ROTATION

Many of our farmers have ruined their land by a one crop system, and many of the complaints about the failure of potato growing on a given area are due, not to unsuitable soil and climatic conditions, but rather to the presence of diseases which have been introduced thru continuous cropping of potatoes, and also to the burning out of vegetable matter in the soil, which is greatly hastened by the continued growing of cultivated crops. It is a safe rule to go by that potatoes should not be planted on the same land more than once, or, under extremely favorable conditions, twice in succession. In other words, rotation with other crops is necessary.

The potato requires an open, porous soil, perfectly drained, and rich in vegetable matter. For this reason, it fits in well with the rotation of other farm crops, and should always follow a crop of alfalfa, either immediately or the second year after. The turning under of alfalfa adds to the soil the needed fiber and improves the condition so that potatoes can develop normally. There is a tendency to grow potatoes on the same land year after year, especially if the land was originally well suited for this crop, but such practice generally brings disastrous results. It is far better to reduce the acreage of potatoes than to plant land that is not in the right condition for the production of an average crop.

In Colorado, where alfalfa is easily grown, potatoes should follow it in a five to six years rotation. The rotation system should be as follows: Potatoes first year, followed with grain and seeding alfalfa the second year; third, fourth and fifth years in alfalfa, and the sixth year, back to potatoes. On the small farm this would mean a reduced acreage, but the grower will find that the net returns would be much greater because of increased yield.

In many of the higher mountain valleys, where alfalfa cannot be grown so successfully, clover and timothy should be substituted

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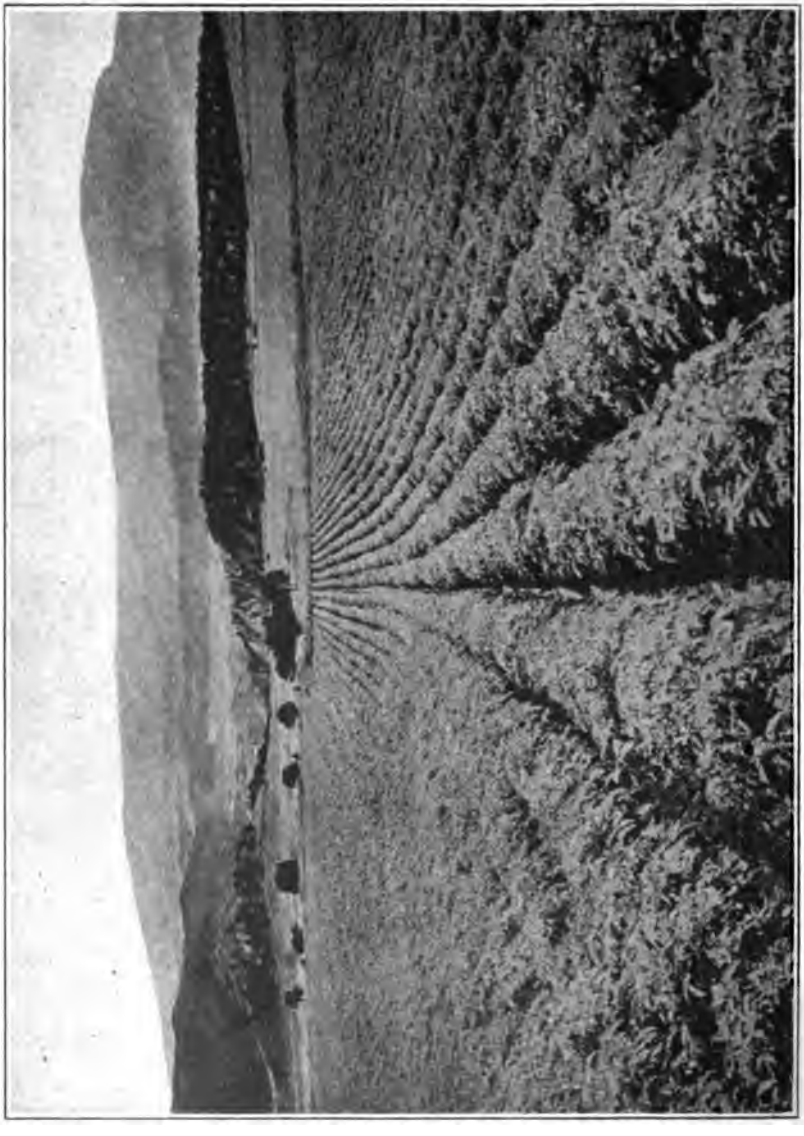

Showing a typical Mountain Valley potato field at Carbondale, Colorado.

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and the rotation period may be shortened to four years. In this case, larger acreages may be planted to potatoes. Not only would the average yield of potatoes per acre be greatly increased, but a corrsponding increase in the yield of grain per acre would be attained following a crop of potatoes.

If this system of crop rotation could be extended from six to eight, or even ten years, leaving the land in alfalfa for a longer period, even better results would be obtained. Long rotation period is only suited for large farms in combination with extensive live-stock operations.

PREPARATION OF THE LAND

The preparation of the land intended for potato growing should be thoro, as the potato develops its crop below the ground, and needs a loose, open soil so that the tubers can expand normally, and also to give the root system a chance to develop to its fullest extent. On the heavier soils, deep fall plowing is necessary, as it gives the elements a chance to act upon the land during the winter. Then again, the land should be plowed a couple of weeks before planting and kept cultivated so as to conserve the moisture stored in the soil during the winter months. When alfalfa is turned under, this may be done in the fall, but shallow plowing in this case is necessary, just deep enough to cut the crown of the alfalfa plants. Deep plowing will not kill all the alfalfa roots. The field should be cross-plowed again in the spring to the depth of eight to ten inches. Deep plowing is a very important factor in the preparation of potato land, so as to give the roots the largest possible feeding area. Where the soil conditions are favorable, the potato plant will send its roots down to the depth of three feet, while if the soil conditions are unfavorable, the root system is confined to the top soil and the food supply curtailed, and the yield will correspond with the food supply. If the spring plowing is done early, the land should be kept harrowed to keep it in fine tilth until planting time. The preparation of the land is really one of the most important factors in potato production, and unless a grower is willing to take the time and perform this work thoroly, he cannot expect a large return.

PLANTING

The depth at which potatoes should be planted varies with the character of the soil, locality and method of culture. When high hilling or ridging is practiced, the planting is shallow—about two inches below the level of the field. On heavy soil the planting may be more shallow. When low hilling is practiced, the planting should be from three to four inches deep, depending upon the character of the soil—the lighter the soil, the deeper the planting.

The time of planting necessarily depends upon the season and

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whether early or late crops are wanted. It generally requires four months to grow a crop of late potatoes normally. This time may be shorter, but if shortened it is generally at the expense of quality. It is better to let the plant develop normally than first to stunt the growth and afterwards hasten it.

Planters.—There are two general types of planters on the market, and in use,—one known as the "picker" and the other as the "disk" type. Both of these types have their advocates. The picker is perhaps less accurate, as it will not always spear a seed—or it may spear the seed in the only bud or eye of that particular seed, thus causing a miss in the stand.

The disk type of machine has to be operated by two persons—one driving and one sitting behind and seeing to it that each compartment in the disk has a seed. In this way, there can be no miss, if the person behind attends to his business.

It costs more to plant a given acreage with the last mentioned type of machine, but if the seed is good and other conditions are favorable, a perfect stand may be obtained.

The importance of a perfect stand is hardly ever realized by the grower.

The average stand of hills in the potato fields in Colorado is only between 75 and 80 per cent. The losses from this neglect alone is fully 20 per cent of the total yield of the State. Practically, a perfect stand is rarely possible, tho at least a 90 per cent stand should be obtained.

SEED POTATOES

The importance of good seed is too often overlooked by potato growers, and more failures result from the planting of poor seed than from any other cause. We speak of seed potatoes in the same sense that we do of seed grains, while in reality we are not planting seed, but cuttings. The potato, itself, is an underground stem greatly enlarged, and serves as a storehouse in which food for the future plant is stored up, and this underground stem or potato is either planted whole or in pieces. The eyes of the potato are equivalent to the buds on the stem of a plant. They perform the same functions in plant economy. When potatoes are exposed to light for a considerable length of time, the green color, or cholorophyll develops.

The common method of obtaining potato seed is well known. Generally, it is the small potatoes which go thru the grader, or, in some cases, the potatoes left over in the cellar or pit at planting time that are used. These methods of obtaining seed for planting are to say the least, poor. It reverses the practice that we are following in the selection of seed grain and in the selection of breed-

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ing of stock for animals. It also reverses the common practice of gardeners in taking propagating stock from the best plants, instead of taking them from the poorest.

The common complaint that potatoes "run out" is due not to the potatoes "running out" of themselves, but to the planting of tubers from the poorest hills and the poorest potatoes of good hills. When this process of selection downward has been continued for a few years, the result is disastrous to the grower, and instead of blaming himself for the result, he blames it to the "running out" of the potatoes. The potatoes do not run out—it is really the farmer who runs the potatoes out. It stands to reason that if a given variety is adapted to the soil and climatic conditions of a given section, that that variety, if proper care is taken in seed selection, will continue to give good results, and instead of showing a decrease in yield, actually show an increase. This is especially true where the soil and climatic conditions are favorable for the development of the potato plant. It is not true in sections where the soil and climatic conditions are not favorable to the plants. In these sections the importation and the planting of seed from more favorable sections is always advisable.

MATURE SEED vs. IMMATURE SEED

The potato being botanically an underground stem, has perhaps a greater bud activity before maturity than after. This has led many to believe that immature seed, that is, seed that has not reached its full growth, but ripened off before this has been attained, is better for seed purposes than seed that has matured in the normal way. While theoretically, the buds may be more alive or more active in partly matured potatoes, it is not true so far as the value for seed is concerned. It is true that the terminal bud and cluster of buds in the immature potato are more active than in the fully mature one, but the eyes or buds located on the stem half of the immature tubers are really less developed than on a fully mature tuber, and this is the real reason why an immature tuber has, in many instances, given better results than fully mature tubers, for seed. In other words, immature tubers planted whole will develop one strong shoot, the terminal one, while the rest of the buds or eyes may never reach the top of the soil, thus producing a strong vigorous plant with one main shoot—an ideal plant for the grower. Where such seed can be obtained, it is undoubtedly preferable to use fully mature seed.

The development of a prominent terminal bud is especially noticeable in certain varieties of potatoes, particularly potatoes of the Peachblow type, and, so far as this particular variety is concern-

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ed, whole seed is preferable to cut seed, and immature seed preferable to mature seed. But where soil and climatic conditions are favorable for potato culture, this is less important, and mature seed may be used with equal success.

WHOLE SEED vs. CUT SEED

During the last few years, considerable emphasis has been placed upon the value of whole seed as against cut seed. It is undoubtedly true that in planting whole seed a better stand is obtained. Whole seed naturally has more eyes and hence capable of producing a larger number of shoots. Then, too, in planting whole seed, the terminal eye is most active and will invariably produce a strong shoot. Further, under our uncertain climatic conditions

Seed Potatoes, Peachblow Variety, from Selected Seed; Note Uniformity and Trueness to Type.

at planting time, it is sometimes difficult to obtain a good stand when cut seed is used. This is especially true in dry, poorly prepared soil, when the cut seed has a tendency to decay, resulting in a poor stand. Under such conditions, whole seed is preferable.

The spring of 1916 was very dry and warm in the Greeley district and in some cases the land was in poor state of preparation. Under these conditions, a large percentage of the cut seed rotted, and very poor stands were obtained. On the other hand, where whole seed was used, the stand of plants was normal. These facts would lead us to believe that whole seed should be used where sufficient soil moisture at planting time is uncertain. On the other hand,

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where soil and moisture conditions are normal, cuttings containing one to two eyes are to be preferred above the whole seed, especially when the whole seed are small potatoes obtained from the screenings.

It is universally recognized that hills having a large number of sprouts produce a larger number of small potatoes and a fewer number of marketable potatoes than hills having one or two main sprouts. From this discussion, the question whether the grower should plant whole seed or cut seed will depend upon his local climatic conditions and upon the preparation of the land, and no exact rule can be laid down.

METHODS OF SEED SELECTION

Bin Method.—This method is commonly used by potato growers who wish to keep up the standard of a given variety without

Field Demonstration in Potato Seed Plot, Carbondale, Colorado.

going to the trouble and expense connected with the more thoro method of hill selection. The essential thing to bear in mind in selecting seed potatoes from the bin is to have the correct type for the variety clearly in mind. As a rule, very few growers grow potatoes that are true to name. In most cases, the potatoes are badly mixed, and instead of one single variety, the grower generally has several, and without the knowledge of the standard and type of the different varieties he cannot hope to make an intelligent selection, but by knowing the type and color of the particular variety

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which he wishes to plant he can select from the bin. Those tubers should be selected which most closely correspond with this type.

In making the selection, medium sized potatoes should be chosen, as these will most nearly show the true type. Large, overgrown tubers, as well as small ones, should be discarded. The selection should be done early and before the potatoes have been picked over and the best ones removed. After selection, they should be kept separate until planting time.

While this method will show a noticeable increase in stand and yield above average seed potatoes, it is not a method to recommend

Poor hill and type to select from

Good hill and type to select from

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for those growers who wish to make a more thoro selection and who wish to continuously improve the variety grown. For such growers, the "hill method" is recommended.

Hill Method.—As the name indicates, the selection is made in the field while the potatoes are growing. Hills which are strong and vigorous are selected and staked. At digging time, but before the main field is dug, these hills are dug by hand, and if the potatoes in the hill correspond with the vigor and growth of the vine in the number and size of tubers, they should be saved and kept separately for seed.

If a grower will select 500 hills in this manner and keep those for planting the following spring, he will have a supply of seed potatoes that should be true to type and variety and be superior in vigor and yield to any seed that he can obtain. This method necessitates the use of a seed plot which is described elsewhere in this bulletin.

In hill selection, both large and small tubers should be saved, since a small potato from an otherwise good hill is better for seed than a large tuber from a poor hill. A good potato grower should continue this method of hill selection from year to year, improving the variety both in quality and in yield.

The expense connected with this method of selection is relatively small for the benefits derived. If our growers would follow this method, they would eliminate the necessity of changing seed and the extra expenses connected with the buying of new seed every few years. It may be stated, that under favorable soil and climatic conditions potatoes can be grown continuously in rotation in a given section and will continue to improve and become better adapted to this section if proper seed selection is pursued to keep up the quality and yield of the varieties.

SEED PLOTS

Every potato grower should grow his seed potatoes separately and distinct from his general crop. It need not be a separate field, but they should be planted separately, so that the seed plot can be under special observation during the growing season. Careful watch should be kept over the seed plot and all weak growing plants and plants showing any tendency to attack from diseases should be removed at once, leaving only the best hills to mature. This is a secondary step in selection and will do much towards bringing up the high standard of the seed. Ordinarily, at the end of the first season of the field grown seed, enough should be on hand to make the entire planting from it. Then hill selection should start from this planting. In other words, in order to obtain best results, hill selection should

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be practiced once every two years, so as to keep up and improve the standard in yield and in quality. This may seem an expensive practice, but since the grower has to provide seed for next season's planting, the extra trouble and cost in selecting and keeping the seed separate is small in proportion to the benefits derived. If every grower should follow this practice, we would hear less of run-out seed, and less of poor yields and diseased fields.

In planting potatoes for seed, especially if the seed is to be used for planting whole the following year, it is better to have the seed dropped from eight to ten inches apart in the rows and the rows three feet apart. This will somewhat crowd the plants and will cause them to produce a larger number of seed potatoes of relatively smaller size, that is, of a size best suited for seed purposes. It is also well to delay the planting of the seed plot until the rest of the crop is planted, in some instances, two weeks later than the main crop. The soil for the seed plot need not be better nor be given

A promising Seed Plot of Ed. Clamson, Carbondale, Colorado
Note the strong and vigorous growth of vines

better treatment than that given to the main crop. The main purpose of having a separate seed plot is to keep the behavior of the individual potato plants under close observation.

Roguing.—While the seed plot represents a definite stage in the improvement of a given variety, it does not follow that the grower should rest satisfied with the results obtained. No matter how careful the hill selection has been and how much care has been taken in preparing and planting the seed plot, there will always be a certain number of individual plants that show weakness, either along the line of disease or in lack of growth vigor. These undesirable hills should be removed during the growing season or whenever they are found. The grower should watch his seed plot and

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see to it that all hills that do not come up to the standard, or to the average, are removed and destroyed. This is the most effective method of keeping up the purity of the seed, as well as the productiveness. Further, it eliminates diseased plants and those that show a predisposition to become infected. In fact, it is advisable to follow the method of roguing not only in the seed plot, but in the general field, for considerable improvement can be brought about by a system of roguing in any field of potatoes, whether grown for seed exclusively, or for the general market.

The time and effort expended on this work will be more than repaid in a higher grade of potatoes, besides eliminating diseases in the field and tubers.

CULTIVATING AND HILLING

There is no crop grown on the farm that requires better cultivation or that responds more readily to good cultivation and favorable soil conditions than potatoes. Being a tuber-producing plant, the shape and size of the tubers are adversely affected by a hard, lumpy, and poorly prepared seed-bed. The practice of preparing the soil after planting and during the growing season should be discouraged—as no amount of after-cultivation can properly prepare the land without disturbing the growing crop. Not only should the surface soil be in fine tilth, but also the soil below, to the depth of ten inches. In loose, mellow soil, the feeding roots of the potatoes will often penetrate the soil to a depth of from twenty-four to thirty-six inches.

Cultivation should start soon after planting, using an ordinary spike-toothed harrow, going over the land every few days. When the potatoes are above ground, harrowing should be continued, but the teeth of the harrow should be set slanting so as not to tear up the sprouts. This harrowing will keep the soil in fine tilth and conserve the moisture in the soil, besides keeping the field free from weeds. Ordinarily, at planting time, the soil should contain enough moisture for the potatoes to come up, without resorting to irrigation, especially if the land has been properly handled up to this time. However, there may be seasons when this is impossible, and irrigation has to be given.

Cultivation is more important than irrigation, and the grower should never substitute irrigation for cultivation. After the potatoes are up and too tall for the harrow, the cultivator should be started and kept going until the vines interfere.

Hilling.—Hilling is almost universal among potato growers in the State. This is especially true on the plains east of the mountains where this practice is possibly carried to an extreme. The prac-

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tice of high hilling has grown out of the conception that the potatoes should not come into direct contact with irrigation water, but that the water should be applied from below, and thence move upward into the soil by capillarity. One might argue that it makes no difference whether the tubers get moisture from below or from the side, so long as they are not in contact with the free water.

The writer is inclined to believe that less hilling or lower ridges is preferable to the high ones, as high ridges invariably raise the soil temperature around the tubers to several degrees above that of level soil, thus creating a condition that is not the most favorable for the normal development of the plant. This is especially true of the Eastern Slope where the summer days are hot and the soil temperature becomes correspondingly high In the mountain sections, the grower does not hill his potatoes to the extent done on the Eastern Slope, yet no one would question that the results obtained by those growers are less satisfactory than those obtained on the Eastern Slope.

In the Greeley section, high hilling is almost universally practiced, and is looked upon as essential to success. While high hilling may be successful during certain seasons, it is also true that during a warm, dry season, lower ridges would tend to keep the soil temperature lower and thus furnish better conditions for the potato plant.

IRRIGATION

The Horticultural Department is frequently called upon to give advice as to when and how potatoes should be irrigated. To answer such questions intelligently, a knowledge of soil conditions is absolutely necessary. Many growers believe that potatoes should not be irrigated until the vines are setting the tubers, even tho the vines are actually suffering from lack of water. This may work out all right, but one may well question the wisdom of following such a rule. It is universally the rule that when a growing plant needs water and shows signs of wilting, water should be applied, so that the normal growth will not be checked. When the tubers have once set, it is necessary to irrigate so as to keep the soil in best growing condition possible for the balance of the season, or until the crop is matured. In other words, there should be no check to the growth of the plants after the tubers have once started to develop. If a check is given during this period and the plant resumes its growth afterwards, knobby and gnarly tubers result. Hence the importance of keeping the young potatoes growing without check thruout the period.

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In irrigating potatoes, it is much better to apply enough water to thoroly saturate the ground, rather than small amounts of water at frequent intervals, as frequent applications of water will puddle and harden the soil to a much greater extent. Also, a small stream running for a long period is better than a large stream for a short period.

On the Eastern Slope, it is preferable to apply the water during cloudy days or at night time. When the potatoes have reached their full growth, which depends largely upon the season and locality, it is advisable to withhold the water so that the skin of the tubers may ripen and harden. Otherwise, the keeping quality of the potatoes will be impaired.

There is a tendency in some potato growing sections to crowd the growth and development, or, as some express it, to make the crop "in the shortest possible time," generally during the month of August and half of September—by the liberal use of water. This practice may be advantageous during favorable seasons, but such practice invariably results in a poorer quality of the crop produced and the tubers are watery and soggy, with poor keeping qualities. Further, seed potatoes grown in this way lack vigor. A normal growth development when the plant is not forced is preferable, so far as quality is concerned. It is also probable that unduly forcing the plants makes them more susceptible to disease attack.

HARVESTING

For the main crop, harvesting should not be done until the vines are dead and the skin of the tubers hardened or ripe, so as to stand the necessary handling before reaching the consumer. If the skin is not hard, it will peel and bruise, and wherever the bruises occur, there will be dark areas which have to be pared away before the potato can be consumed as food. The keeping qualities, too, are greatly impaired from immaturity, as the bruised areas invite the attack of fungi, causing decay.

If the vines are still alive and growing when frost occurs, the potatoes in the ground at this time are necessarily in the growing stage and are not fit for harvesting. They should be left in the ground as long as possible, so as to give the tubers a chance to ripen. The digging should be done when the weather conditions are most favorable and the soil is not water-logged. It is advisable to leave the potatoes on top of the ground for two or three hours to permit them to dry off before they are sacked. Where the potatoes are placed in cellars, the importance of field curing cannot be overemphasized, as a considerable portion of the losses occurring in storage is due to poor grading and to imperfectly dried potatoes when placed in storage. Whether sold directly from the field or

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placed in storage, the small and bruised potatoes should be eliminated.

In digging the potatoes, enough horse-power should be utilized so that the digger will get under the hills—otherwise, many potatoes will be cut and spoiled. It is much more economical to use an extra horse, or even two, so as to be able to have the machine go to the required depth. The extra cost is more than repaid, first, in getting all the potatoes out of the ground, and second, in eliminating cut or bruised tubers which cannot be sold. Practically all of the potato digging machinery now on the market is satisfactory, if properly used. We do not recommend any particular make over others.

GRADING (STANDARDIZATION)

Less attention has been paid to the grading and standardizing of potatoes than any other agricultural crop. Most of the agricultural products are bought and sold on grades or standards, while in the case of potatoes, each grower seems to establish his own standard, and, as a consequence, the purchaser does not know what he is getting until he has an opportunity of inspecting his purchase. There is more waste in this crop than any other grown on the farm, and this waste could be entirely prevented by the grower. It has been estimated that from 15% to 20% of the total potato crop placed on the market is below commercial standards and should never have left the farm. This would mean that out of the total yield of 350 000,000 bushels in America, 15%, or 52,500,000 bushels are virtually thrown away. Besides this waste, the grower, in addition, is paying for containers, railroad freight, and hauling and cost of marketing in handling these 52,500,000 bushels, and finally, he is lowering the actual value of the whole crop, by selling inferior products. It is a great economic loss, since this 15% is not utilized for any purpose, but is thrown away by the consumers, while if left on the farm it could be utilized as a food for livestock. There should be a standard grade or grades of potatoes the same as we have standard grades for the grains, and the crop should be priced on these standards. In order to accomplish this, the grower must pay more attention to the grading side of his work. At present, most of the potatoes are graded in the field, being run over a grading machine. The machine, under the best conditions, will not grade the potatoes properly, but under the conditions that the grading is done in order to follow up the digger, the potatoes are poured over the grader and only a small proportion of the undersized potatoes are taken out. More than half of the small tubers go into the sacks, together with gnarly, cut, and diseased tubers.

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In some instances, the grower, in order to swell the total yield per acre will go to the trouble of stretching gunny sacks over the grader so as to prevent any of the smaller potatoes from getting thru. In such cases, it would be more economical if the grading were entirely dispensed with.

The potatoes should be graded at least into two sizes—from four to twelve ounces, and from twelve ounces up. This would not mean that the potatoes would have to be weighed individually any more than in grading apples, but it would produce a uniform product, so that the buyer would know what he was getting, and the consumer would not have to buy small potatoes and earth with the marketable tubers. The extra cost for grading would be more than compensated for by the higher prices obtained, and in the utilization of inferior potatoes as food on the farm.

There are commercial graders of the improved type now on the market, and should be utilized by the grower. The only way to obtain uniformity in grading and packing would be to have a community grader where all potatoes in a community could be graded at one place before being loaded on board a car. By such method, the whole crop could be taken from the field and hauled to the grader, and run thru the same, returning to the grower the inferior product to be taken back to the farm for feeding purposes. In most cases, the community grader should be located at the loading station.

So long as grading is left to the individual grower, so long will the present confusion and disorganization exist, and so long will the grower obtain a lower price for his product. There are a great number of instances that have come under our observation where buyers have re-sorted or re-graded the crop bought from the grower and sold them at a higher price—more than paying for the cost of grading and the loss in weight.

The question of uniform packages is also important. There is no reason why a sack of potatoes should not have a standard weight, either 100 or 120 pounds. This would eliminate considerable trouble and make it easier to keep track of sales, as each sack or each container would weigh the same.

The question of using boxes as containers for potatoes has been agitated and met with more or less favor. Personally, we believe in the box as a package for potatoes, especially if special grades are put up in this way. The potatoes will suffer less in handling, and besides, would provide a convenient package for the small household to buy. But the box is not the proper package for the average grower under the present conditions, as the potatoes, in some cases, would not be worth more than the box. Where the

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box has been used to put up high grade potatoes for fancy trade, it has been a success.

One of the aims of the Colorado State Potato Growers' Association is to establish standard grades and containers so that the buyers will know what they are buying. The importance of the potato crop as a universal human food makes it all the more necessary that it should be marketed and sold under certain required standards.

SEED CERTIFICATION

With the development of the potato growing industry in this State, some provisions are necessary to secure the purchaser of seed potatoes against inferior product. To obtain this condition a system of seed certification is necessary. It is true that here and there, are seed producers who make a specialty of producing high grade potatoes from which the average grower may obtain high class seed. But these seed growers are few and far between, and as the welfare of an industry depends upon the intelligence and standards of the average grower, it is necessary that the largest possible number of them should have access to high grade seed.

A system of seed certification by properly qualified officials who can certify to the quality of the seed is necessary. This would tend to raise the general standard of the product, and also furnish an incentive to many growers to produce certified seed.

A system of certification was formulated by the Colorado State Potato Growers' Association and incorporated in its constitution and by-laws. This certification calls for two inspections of the growing field during the summer, and a bin inspection after the harvest. In the field inspection special attention is paid to the health and vigor of the plants, the absence or presence of disease, the fullness of the stand and the uniformity of the plants in the field. The two field inspections should be made at intervals of four to six weeks. The last inspection should be made as late as possible before the harvest, so as to detect the most dangerous diseases.

The bin inspection gives the inspector an opportunity to determine the trueness to type of the variety grown, the freedom from scab and the general quality of the tubers. If, after the inspection, the inspector finds that the product measures up to the standard, a certificate to this effect is granted to the grower. This certificate states the variety, the results of the inspection, and in fact all possible information connected with the potatoes. The grower may then use his certificate in advertising his product and

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the fact that his potatoes have passed the necessary inspection gives the grower a prestige over those who do not hold such certificate.

It is a fact that the Colorado potato growers every year find considerable difficulty in obtaining first-class seed. This is especially true during a year like the present one when prices were abnormally high and where the grower disposed of his product regardless of standards. A year of extremely high prices tends to demoralize standards, but the grower should bear in mind that extremely high prices are the exception rather than the rule with a standard crop like potatoes, and the success of a grower is not based alone upon the large profit obtained in a single season. We must provide for the average years and average prices and raise the standard of the product so that during the year of average prices the grower still can make a profit and find a market because of the excellency of the tubers produced.

A State law fixing standards both as to grading and seed would be beneficial to the grower, but it is doubtful if such law could be passed until there is greater demand for it. Meanwhile, it is the duty of organizations and individuals to do everything possible to raise the general standard of the crop.

Our potato growers do not realize the future before them in the production of high grade potato seed for the Southern planters. This phase of potato growing has unlimited possibilities, as the demand for high grade seed is constantly growing. Colorado is the natural territory to supply the seed for this section of the country, not only because of the advantages in soil and climate, but also because of the nearness to the markets and the lower transportation charges.

The demand for seed potatoes from the South calls for the growing of varieties that are not now grown to any extent. The varieties in demand for seed are the Cobbler and the Triumph. Both of these can be successfully grown in most parts of the State. From all indications, the Triumph is well adapted to the conditions in the San Luis Valley, while the Cobbler can be grown successfully in every section of the State.

This department has had numerous requests for seed potatoes of these two varieties from the South, and these requests have been more numerous during the last two years than before, indicating that the Southern growers are beginning to learn the value of Colorado grown seed.

QUALITY OF COLORADO POTATOES

It is generally understood that quality in potatoes is guaged on the character of the cooked product. Mealiness and uniformity in cooking being the two important points. Mealiness is more or

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less associated with the starch content of the tubers, and the amount of starch present in turn dependent upon soil and climatic conditions, especially those of rainfall.

From determinations made of Colorado potatoes and those grown in other states, it would seem to indicate that the Colorado potatoes have a higher starch content, and hence should have better quality, tho this may not always be true, as quality may, to a large degree, be determined by local conditions during the growing season. Too much rain or too much water in irrigation will invariably produce a soggy potato, and hence a potato of low quality.

The climatic conditions of Colorado are eminently adapted to the production of high quality potatoes if proper precautions are taken in the use of irrigation water. Records show conclusively that over-irrigation here is just as harmful against the production of high quality of potatoes as an excessively rainy season is in the Eastern states, and that the Colorado grower may, and sometimes does, produce potatoes of inferior quality.

DEGENERACY OF POTATOES

During the last few years, a considerable amount of investigational work has been done to determine what factors are responsible for the general decline of a given variety in a given locality. These experiments seem to agree that the different varieties as generally grown in a section do show a decline in productiveness and in type. This degeneracy or decline was not confined to any particular variety, nor to fields where poor seed was used in planting. In many cases degenerate hills were found in fields that were planted to the best seed obtainable. This seems to indicate that the potato is more or less variable even under the best conditions, and calls for a greater care in selecting seed, especially in the selection of hills for future seed production.

This universal tendency towards degeneracy or decline may possibly be due to a physiological condition inherent with the potatoes. The fact that the tuber is a highly specialized part of the plant and one that has developed by repeated selection and breeding, and further, its development being dependent upon factors of soil and climate, would make the question of retaining a permanent type of a given variety difficult, and by the very nature of the plant, variable. This undoubtedly being a fact, the question of careful selection by the hill method becomes more important, if we are to retain the essential qualities we wish to perpetuate. A given variety cannot be made to retain its desirable qualities without constant care in selection and cultural methods.

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STORAGE

Pits and Cellars.—Pits are not utilized in the West to the extent that they are in the East. Many of our potato growers have now regular cellars for storage which fulfill all the requirements. Storage cellars are really necessary structures in connection with potato growing, as they enable the growers to avail themselves of higher prices which usually follow harvest time. Where potatoes are grown on a smaller scale, the pit can be utilized without any material loss of the crop. In fact, potatoes stored in pits properly made are as good, or better, in the spring than potatoes stored in cellars.

The following method of pit construction has been employed by the writer, with complete success:

Level off a piece of ground of sufficient size to hold the potatoes intended for storage, then excavate to the depth of four inches, and

An Up-to-date Potato Cellar; Capacity 25,000 bushels; at Carbondale, Colorado.

use the earth taken from the excavation as sides, that is, heap the dirt up along the edges of the cleared space. This cleared space should then be firmed down and the potatoes piled into this area. A convenient size for the pit is ten feet in width, making it any length needed. The ten feet should measure from embankment to embankment.

The potatoes should be piled up in the shape of a pyramid, or like the roof of a house, making the pitch to the sides as steep as possible, and yet keep the potatoes in place.

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It is necessary to do a little hand work in finishing off the sides after the potatoes have been dumped into the pit.

When the potatoes are in proper position, they should be covered with a layer of clean, dry straw, or clean, dry marsh hay, not less than two feet in thickness, and just enough earth put on the same to hold the straw in position. In some cases, it is advisable to use poles or rafters to hold the straw down, instead of earth. The pit should be left in this condition until cold weather sets in. The straw is sufficient to keep out ordinary frost, and it will keep the pile ventilated and permit surplus moisture to escape. As cold weather approaches, a thin layer of earth is added. Every three or four feet at the apex of the pile, openings in the earth should be left to permit moisture to escape. It is also advisable to keep openings at the base of the pit, but these openings should be covered with straw so that the frost will not get in, and before winter arrives, more earth covering should be applied, the amount depending upon the severity of the weather. When regular winter sets in, more earth should be added to the covering. If very cold weather should occur, a coating of stable manure on top of the earth is advisable. The ventilators at the top and at the bottom should be entirely closed during the cold weather.

It is very important that the potatoes be dry and free from rot when stored in pits.

VARIETIES OF POTATOES

In a State like Colorado where the soil, altitude and climatic conditions are so varied, the choice of varieties to plant becomes, to a great extent, a local question.

In the Greeley section, the Pearl and the Rural are grown almost exclusively for the main crop and the Early Ohio for the early crop. The rural variety is better adapted to the heavy soils and to plains conditions than the Pearl. The latter is inclined to grow rough and ill-shaped on heavy soil, while on lighter or loamy soils, the Pearl is preferred.

In the San Luis Valley the Barklay's Prolific, Russet Burbank, Rural and Pearl are the leading varieties. Barklay's Prolific is grown most extensively and is admirably adapted to this section. It is a heavy yielder, is of excellent cooking qualities, and stands shipment better than almost any other variety grown. It will be more extensively planted in the future than in the past. This variety is not true white, but has a golden brownish tint that does not in any way detract from its salability. Barklay's Prolific is probably only a local name. Early varieties are not grown to any extent in this section, due to late spring frosts. The Irish Cobbler is admirably adapted and is grown to a limited extent. The Triumph

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has also been grown to a very small extent and indications are that this variety will do well. The San Luis Valley has a future before it as a seed-growing center for Southern trade. Cobbler and Triumph for this trade always bring a high price and are in great demand.

In the Carbondale and Eagle River district, Peachblow, Russet Burbank, Rural and the Peoples are the late varieties grown extensively. The Peachblow reaches its highest perfection in this section and is grown extensively. There is some objection to a colored potato for the main crop as the market is somewhat limited, especially for markets outside of the State. On this account, the acreage planted with this variety is on the decline. Irish Cobblers are grown for an early crop.

Grand River Valley, Gunnison and Uncompahgre Valleys devote a large acreage to early potatoes. The varieties grown are the Irish Cobbler, Downing, and Early Ohio. Late varieties are the Pearl, Russet Burbank, and Rural.

In the Northwestern section the main attention is paid to medium early varieties, due to the shortness of the growing season. Russet Burbank and Pearl are the leading varieties. Few, if any, early varieties are grown in this section.

It will be noticed from the above discussion that relatively few varieties are grown in commercial quantities in the State. This is an encouraging condition, as it eliminates a mixture which is undesirable in commercial shipments. It also aids in keeping the varieties true to name so that a definite standard can be obtained for each section.

While a number of other varieties have been tried in different sections of the State, our growers realize that by paying attention to proper seed selection, a satisfactory yield can be obtained from year to year without introducing new varieties. There is a considerable difference in the adaptability of different varieties to different types of soil. For example, it is not advisable to grow the Russet Burbank on heavy soils, nor on soil that is extremely fertile. For, under such conditions, this variety produces over-grown and ill-shaped tubers which are not desirable, while on light, mellow, and moderately fertile soil it is very satisfactory.

Farmers who expect to grow a large acreage in any of our potato growing sections should make careful inquiries as to varieties and the type of soil on which they are grown, so as to eliminate losses from growing varieties ill-suited to the locality.

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POTATO DISEASES

Late Blight.—This disease so destructive in the East does not occur in Colorado. At least it has done no damage so far as we know.

Early Blight.—It occurs in the State, and, under favorable conditions, does considerable damage. The favorable conditions are, high temperature accompanied with high humidity. The disease generally occurs late in July and early in August, and is easily distinguishable by dark brown patches and rings on the foliage. In extreme cases, the whole foliage of the plant becomes affected and may drop off and kill the plant so far as future growth is concerned. This greatly reduces the yield, as the potatoes do not have time to develop to their normal size. So far as we know, the disease is confined to the foliage in this State and does not seem to attack the tubers.

Spraying with Bordeaux Mixture before the disease appears will, if thoroly done, prevent its appearance, but after the disease has once gotten a foothold and becomes distributed over the field, the application of Bordeaux will not eradicate it. Bordeaux Mixture is not a cure, but a preventative. Due to the fact that Early Blight does not occur annually, but only during favorable seasons, our growers, as a rule, do not spray to insure their crop against losses from this trouble, tho yearly application of Bordeaux to the potato vines would insure against its appearance and the losses caused by it.

Fusarium Disease.—This disease is found in every potato growing section of the State and is the most destructive disease with which the potato grower has to deal. The disease is favored by high temperature, moisture and poor soil drainage. In heavy adobe soil, the disease appears to be particularly bad. It is introduced into the soil either by a previous crop, or thru diseased seed potatoes. The fact that the disease may remain in the soil for more than one year makes the subject of rotation important to the potato grower, and it is one of the reasons why we advocate growing potatoes only one year on the same piece of land without the intervention of other crops.

The most common way of dissemination of this disease is by the seed. The grower can easily ascertain for himself whether the seed potatoes are free from *Fusarium* or not by cutting off a thin slice at the stem end. (See figure 8.) If the meat on the cut surface of the tuber shows a dark circle extending around it, this indicates the presence of the disease, and such seed should not be planted, as it will work its way thru the seed potato up to the stem and

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destroy the whole plant. Such seed may be used for feeding animals, but should under no circumstances be planted.

There is no known remedy that is effective against this disease: only precautionary measures can be taken, such as rotation of the crop and the planting of seed free from the disease.

The appearance of the disease in the field is, in some cases, almost identical with the Early Blight, with the exception that the leaves turn a paler shade of yellow and do not show the brown patches and circles. The stem is also attacked, and if a cross-section is made of the stem close to the ground, dark areas will be found in the bundle or fiber portion of the stem. These dark areas indicate the presence of the disease, and greatly interfere with the transportation of food materials up and down these fibers or vessels in the stem. It is also maintained that the curling of the leaves sometimes present in many of our potato fields is caused directly or indirectly by the same fungus. Undoubtedly other factors contribute to the presence of the trouble known as the "Curly Leaf Disease."

Rhizoctonia.—This disease is present in practically all of our cultivated fields, and under favorable conditions will do considerable damage to the crop. The presence of the disease on the vines can be distinguished by dry rot or lesions that occur at the base of the stem from the ground upward. In some cases these lesions or wounds extend around the whole stem and completely shut off the food supply. In other cases, the disease attacks only one side of the stem and does not completely cut off the supply of food to the roots, but curtails the food supply and lessens the production of tubers. The disease may occasionally be found on the potatoes in the form of black spots or wart-like growths all over the skin. (See figure No. 9.) These little areas vary in size from a pin-head to the size of a dime. They are black and corky in structure and are known as sclerotia. These structures carry the spores over from year to year and reinfest the crop. A careful examination of potato fields in the State this year show that this disease is very prevalent. In one section of the State the writer was unable to find a single tuber that did not have some sclerotia present on it. This disease seems to thrive on dry land as well as on that which is irrigated, but seldom develops to a dangerous point on the dry lands.

The disease can be controlled, so far as disseminating it from diseased tubers is concerned, by means of disinfection. The most effective method is a corrosive sublimate treatment, using 4 ounces of corrosive sublimate in 30 gallons of water. The solution may be made up in a barrel and the potatoes placed in a gunny

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sack and kept suspended in the solution for from an hour and a half to two hours. This solution will penetrate the sclerotia and kill the spores, after which the seed can be planted with safety, so far as this disease is concerned. The potatoes treated cannot be used for feeding livestock, as the solution is exceedingly poisonous. The solution may be used three to four times, after which a new mixture should be made.

Potato Scab.—This well-known disease is common in every section of the State, and during some years does considerable damage to the crop. The disease is external, penetrating the tubers only to a very small extent. Its greatest damage is to the appearance and keeping quality.

There is very little excuse for the existence of this disease, as it can easily be controlled by treating the seed potatoes. The same treatment as recommended for the *Rhizoctonia* disease should be used, that is, the potatoes, before cut, should be dipped into a solution containing 4 ounces of corrosive sublimate to 30 gallons of water. The easiest way of treating the seed is to make up the solution in a barrel holding about fifty gallons. The barrel should contain about thirty gallons of the solution and the potatoes placed in a gunny sack and suspended in the solution for an hour and a half, after which the seed may be cut and planted. Precautions should be taken not to feed the treated seed to livestock, as the poison is very deadly.

Numerous complaints have been received that the scab has occurred in some fields in spite of treatment, and often when clean seed has been used. In such cases the presence of the scab fungus is undoubtedly due to the feeding of cattle on the field the season before planting. This disease propagates very readily on the manure dropped by the cattle, and in this way the land becomes infested. If the disease is in the soil, the treatment of the seed potatoes cannot be effective against it. Clean land, as well as clean seed, is essential for the production of clean tubers.

CELLAR FUMIGATION

One of the fertile sources of loss in potato storage is due to poor and disease-infested cellars. The cellar should be cleaned out and fumigated every spring after potatoes and other stored articles have been removed.

The best method of cellar fumigation is undoubtedly the formalin permanganate method. The following formula is recommended:

For every 1,000 cubic feet of cellar space, 3 pints of formaldehyde and 23 ounces of potassium permanganate. The permanga-

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FUSARIUM DISEASE

RHIZOCTONIA DISEASE

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nate is placed in a shallow dish or earthen vessel and the formaldehyde solution is poured over it. The operator must leave the cellar immediately and close it up tightly to escape the fumes. If the cellar is large and requires large quantities of chemicals, several vessels or dishes should be used, placing them in different portions of the cellar so that the fumigation may be more uniform. The cellar should be left closed for 48 hours, or longer.

ACKNOWLEDGMENT

The writer wishes to thank Mr. Lou D. Sweet, of Denver, for the loan of several of the illustrations in this bulletin.

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AVAILABLE BULLETINS

Any of the following bulletins will be sent free to those who request them so long as the supply lasts. C. P. GILLETTE, Director.

No.

150 Measurement and Division of Water, by L. G. Carpenter.

183 Deterioration in Quality of Sugar Beets Due to Nitrates Formed in the Soil, by Wm. P. Headden.

189 Cost of Beef Production on Enclosed Range, by G. E. Morton.

190 Variation Studies in Brome Grass, by Alvin Kezer.

192 Home-made Cider Vinegar, by W. G. Sackett.

193 Nitrifying Efficiency of Certain Colorado Soils, by W. G. Sackett.

194 Frictional Resistance in Artificial Waterways, by V. M. Cone.

195 Small Fruits for Colorado, by E. P. Sandsten.

196 Some Soil Changes Produced by Micro-organisms, by W. G. Sackett.

198 The Onion in Colorado, by E. R. Bennett.

199 Vegetable Growing in Colorado; Hot Beds and Cold Frames; Common Insects of the Garden, by R. A. McGinty and C. P. Gillette.

200 Silos and Silage in Colorado, by H. E. Dvorachek.

201 Some Colorado Mushrooms, by B. O. Longyear.

202 Testing and Handling of Milk and Cream, by Roud McCann.

203 Costs on the Colorado Agricultural College Farm, by Alvin Kezer.

205 Yellow-berry in Wheat, by Wm. P. Headden.

206 Spur Blight of the Red Respberry Caused by **Sphaerella rubina**, by W. G. Sackett.

208 A Study of Colorado Wheat, Part I, by Wm. P. Headden.

209 Irrigated Agriculture in the San Luis Valley, by V. M. Cone and A. Kezer.

210 Insects and Insecticides, by C. P. Gillette and G. M. List.

211 Colorado Plants Injurious to Live Stock, by Geo. H. Glover and W. W. Robbins.

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220 Potato Growing in Colorado, by E. P. Sandsten.

221 Hot Beds and Cold Frames, by T. F. Limbocker.

222 Forcing of Strawberries Under Glass, by Florence I. Kinnison.

223 A Fruit Survey of Mesa County, by E. P. Sandsten.

224 Native Vegetation of Colorado in Their Relation to Agriculture, by W. W. Robbins.

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Bulletin 221 January, 1917

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

HOTBEDS AND COLD FRAMES

BY

T. F. LIMBOCKER

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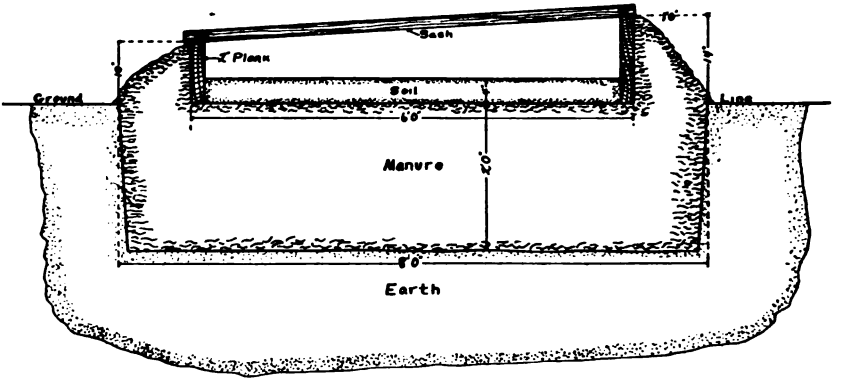
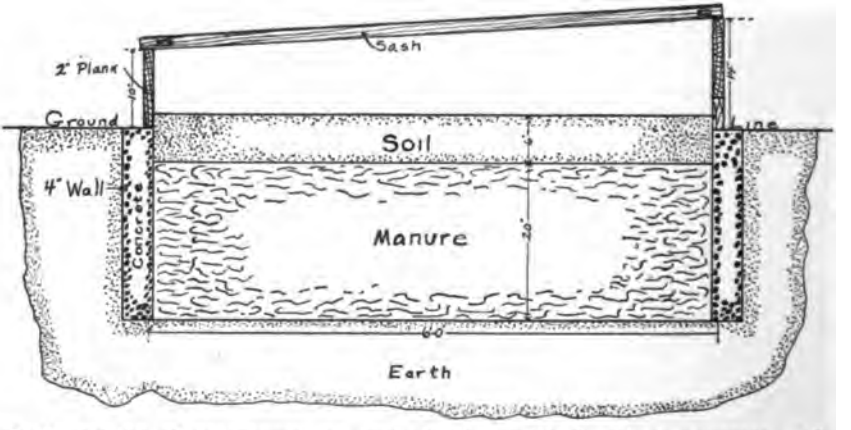
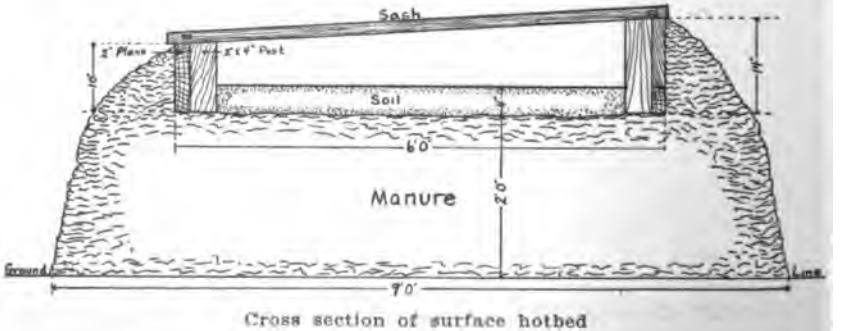


Cross section of a temporary, unlined pit hotbed.



Cross section of permanent pit hotbed, lined with four-inch concrete wall.



Cross section of surface hotbed

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HOTBEDS AND COLD FRAMES

By T. F. LIMBOCKER

Hotbeds and cold frames are so essential to gardening, so easily made and operated, yet so little used, that this pamphlet has been prepared to give briefly their construction, uses and management. By means of these devices fresh vegetables may be had out of their usual season.

Hotbeds are used for growing short-season vegetables (lettuce, radishes, etc.) to maturity, and for starting other garden crops so that they may be well advanced for planting out when warm weather arrives.

Cold frames are used to carry half-hardy plants over winter for planting the next spring and for starting, hardening off, or maturing plants when only slight protection is needed.

DEFINITIONS

Hotbed.—A bed heated from the bottom by means of pipes, flues or fermenting organic matter (manure, leaves, etc.), used for seed germination and plant growing.

Cold frame.—An unheated frame for protecting plants from frost.

LOCATION OF BEDS

A hotbed or cold frame should, if possible, have protection against the north and northwest winds and be located preferably on ground with a gentle slope to the south. It is best to have the beds where they will be passed frequently so that they will receive proper attention.

CONSTRUCTION OF HOTBEDS

Hotbeds are usually built 6 feet wide and some multiple of 3 feet in length, so that the ordinary hotbed sash may be used to cover them. A 6x12 ft. bed will produce enough plants for use in an ordinary kitchen garden, or enough short-season vegetables for the average family.

The walls of the frame may be made of concrete, brick or plank. The latter is more commonly used, altho concrete is the best. Particulars are given for 6x12 ft. plank frame hotbeds which are very con-

* The writer wishes to acknowledge his indebtedness to Mr. Hal Goodacre, the College Florist who offered many very helpful suggestions in the preparation of this bulletin.

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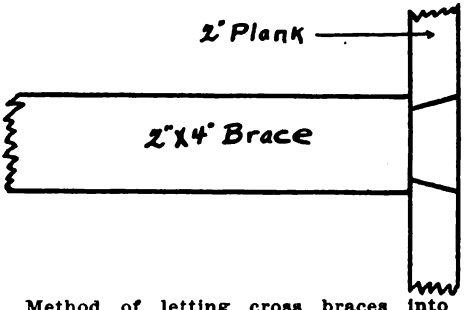
venient for general use. As manure is far the most common heating element for hotbeds, only this kind is described.

Hotbeds are of two general types—pit beds and surface beds.

PIT BEDS

This type of hotbed is so called because the fermenting matter which supplies the heat is put in a pit in the ground. It retains its heating power longest and is most desirable for that reason. It is advisable to get the pit ready when the ground is easily dug and not wait until it is actually needed. These beds may be further classified as temporary pits and permanent pits.

Temporary Pits.—A temporary pit is one which is desired for use only one or two seasons, and is consequently unlined. To make a bed of this kind, build a substantial frame 6 ft. wide and 12 ft. long of 2-inch planks, 14 inches high at the back side and 10 inches high in front, with the ends conforming to the slope. A 2x4 inch cross-piece should be let into the frame flush with the top every 3 feet so that it acts as a brace and helps support the sashes. (See illustration.)



Method of letting cross braces into sides of frame, thus avoiding the use of nails and making the removal of the cross braces easy.

Dig a pit 2 feet deep, about 8 feet wide and 14 feet long with the long way running east and west. Fill the pit as described later. When the pit has been filled, set the frame on the manure, bank up around the sides and ends and put on the sashes.

This is a cheap, yet very satisfactory form of hotbed. Since the frame rides on the manure, the whole bed, frame and all, sink together as the manure settles. It is desirable for this to occur rather than for the bed alone to sink, and the frame to remain in place. In this particular the temporary pit is superior to the permanent pits.

Permanent pits are intended for use for several years. They are generally lined with walls of concrete, brick or wood, concrete being the most satisfactory.

To make a 6x12 ft. permanent pit, dig a pit 2 ft. deep and 6 ft. 6 in. wide by 12 ft. 6 in. long, making the bottom level. Put in a 4 in. concrete wall 5 ft. 9 in. by 11 ft. 9 in., inside dimensions, extending to the surface of the ground. On this wall a frame made as described

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above is set. This frame is easily handled by two men and may be moved about as desired.

If it is desired, a double-walled partition of 1 in. boards may be built in the middle of the frame, leaving a 4 in. space between the boards to be filled with soil. Inside of the boards used for the wall a lining of heavy building paper should be put making the wall consist of two 1-inch boards, two thicknesses of building paper and 4 in. of soil. This makes a tight wall and enables the two parts of the pit to be started at different times. When one side of the pit has been filled, the partition should be banked well with manure on the opposite side.

After the frame has been completed, the spaces round it should be filled with soil firmly tamped.

The manure is put in and the bed handled as described later.

This makes a very serviceable pit which will last several years.

SURFACE BEDS

A surface bed is made by putting the manure, when properly heated in a flat pile about 3 ft. high and 3 or 4 ft. longer and wider than the pile is to be. The frame used is the same kind as that described above under temporary pit beds. It is placed on the manure heap and banked up well around the sides. The advantages of this bed are its ease of construction and the economy of space by its use. Since the manure is put on top of the ground, the beds may be cleared away after they have served their purpose and the ground used for later crops. Where land is scarce or expensive, this saving of space is an important factor, and for this reason, surface beds are the more desirable. Especially is this true in commercial gardening. Surface beds have the drawback, however, of losing their heating power sooner than pit hotbeds.

SASHES

Hotbeds and coldframes are generally covered with glass sashes 3 ft. wide and 6 ft. long. These sashes have three rows of glass 10 in. wide. They will cost $2.50 to $3.00 complete, and local dealers will usually order them if they do not have them in stock.

Double-glazed sashes cost about one-half again as much as the single glazed sashes. They are very convenient for use and no mats need be used with them. They contain two rows of glass with a dead air space between. However, they are considerably heavier than the single-glazed sash, and there is a good question whether the advantages justify the additional original cost.

MATS

In very cold weather an additional protection will be needed for the plants. This is best furnished by mats made of grass, straw, rattan

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or waste cotton and wool, which mats may be bought from the dealers. Good mats may be had at from $1.00 to $1.50 each and will last a long time. Satisfactory coverings may be made by stuffing burlap covers with straw. Ordinary gunny sacks, horse-blankets, boards or any other convenient covering may be used.

It is not advisable to leave the covering over the plants any more than necessary, as it causes them to become spindly and yellow from lack of light. When the plants have been covered for a considerable length of time, light should be admitted gradually, as too sudden exposure to sunlight might be fatal to them.

During very cold weather, it is also helpful to bank up the sides and ends of the frame with manure.

HANDLING MANURE

The best manure for hotbeds is from grain-fed horses or mules. It should contain about one-third of its bulk of straw, hay or leaves. The manure should be carefully handled in collecting to prevent excessive decomposition.

About two weeks before time for seeding the hotbed, the manure should be hauled to it and piled in a flat, compact heap 3 to 5 feet high near the hotbed. If the weather is very cold, several buckets of warm water may be added to start the manure to heating. In four or five days the pile should be well heated thruout. It should then be turned inside out, putting the coldest manure on the inside of the heap. When the manure has again heated, the pit should be filled. In filling the pit, put in layers about 6 inches at a time and tramp well, especially around the edges of the pit. If the manure is not moist enough, warm water should be sprinkled over each layer. Enough manure has been used when the pit lacks about 4 inches of being full after the manure has been well tramped. The sashes should be put on and left until the manure has thoroly warmed up, when the soil may be put in. The heating period of a hotbed is usually 8 to 10 weeks. When this is over, the bed may be continued as a coldframe.

SOIL

Good garden loam soil should be used for hotbeds. Four inches of soil is enough for most plants grown in the hotbed, but root crops such as radishes need five or six inches. As the soil is put in, it should be well pulverized, packed and leveled. When this has been completed, it should be watered, if necessary, and the sashes again put on.

SEEDING

For several days after the manure is put in the temperature rises, often going above 125° F. It then begins to fall. When it has lowered to 90° or 85°, the seed may be planted.

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Hotbed or "plunging" thermometers are made for determining the temperatures. In use they are thrust thru the soil into the manure and left until the correct reading is obtained.

The seed should be planted in rows 3 or 4 inches apart. When the plants begin to crowd, they should be thinned or transplanted.

Radishes and lettuce may be planted the latter part of January or early in February; early cabbage, late in February; tomatoes and cauliflower the first week in March; eggplants, peppers, cucumbers and melons about the middle of March. The hotbed should be made, that is, the manure put in, a week to ten days before seeding time.

Plants are sometimes grown in hotbeds in shallow boxes (flats) which are set on the soil. In such cases, only two or three inches of soil are necessary. This is also enough when potted plants are grown. For this purpose the soil may be replaced by sand.

WATERING

Hotbeds require very careful attention in watering. Enough water must be given to keep the soil moist, yet not to wet the manure excessively, as this shortens the heating period and makes the heat uneven.

Occasional thoro irrigations are better than frequent light ones. The sprinkling can with a rose nozzle is best for applying water. This distributes the water more evenly and does not wash the soil as does a hose. Water in the morning when there is bright sunlight. Watering late in the afternoon lowers the temperature at a most critical time and should never be done.

VENTILATION

Unless proper ventilation is given, the plants are likely to die from over-heating. Whenever drops of water collect on the inside of the glass, the sashes must be raised to admit air. In very cold weather it may be necessary only to raise the sashes and lower them almost immediately. As a rule, they may be left raised somewhat during the warm part of the day. Hot, moist air is favorable to "damping off" (the worst hotbed disease) and one must be careful to avoid this by giving sufficient ventilation.

CONSTRUCTION OF COLD FRAMES

Cold frames are built essentially the same as hotbeds, and, like them, are temporary or permanent.

Permanent cold frames are built the same as permanent pit hotbeds, making the pit of the depth required for the particular use to which it is to be put.

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For temporary cold frames the low frames are simply set on the ground where the soil has been made sufficiently rich for growing plants. The frames are made the same as for hotbeds. Cold frames are covered with glass sashes, oiled paper, canvas, or muslin dipped in linseed oil and dried. Glass sashes are best for cold weather, but in the latter part of spring when only a few degrees of frost are had, one of these substitutes may be used.

USES OF COLD FRAMES

Cold frames are used for maturing crops late in the fall, for carrying over winter young plants such as cabbage and cauliflower for planting in the spring, for protecting semi-hardy flowering plants during the winter, for starting plants before the weather is warm enough to plant the seed in the open, and for hardening off before planting in the open young plants grown in the hotbed or greenhouse. Occasionally permanent cold frames are used as storage pits for vegetables, such as celery, cabbage, potatoes and root crops.

For starting plants in the cold frame the seed is sown either in the soil or in flats or pots and set within the frame. Young plants are sufficiently protected from the cold to prevent freezing, as they become hardened enough to withstand light frost. When the weather is mild enough, the plants are transplanted into the open.

A very common form of temporary cold frame in the south consists simply of two parallel rows of planks set up in the field six feet apart and covered with sashes. The seeds are planted in their regular rows between the planks, and when the weather is warm enough the sashes and boards are removed, leaving the plants well started in the field. This process may be reversed in the fall, starting the plants in the open and later putting up the frame to protect them.

Semi-hardy flowering plants like pansies and geraniums are put in cold frames for winter protection. Usually two or three inches of sand or cinders are put in the bed and the pots sunk into them.

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Bulletin 222 February, 1917

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

THE FORCING OF STRAWBERRIES

BY
By FLORENCE I. KINNISON

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FORT COLLINS, COLORADO
1917

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Appearance of Plants When First Placed In Cool House

Forced Fruit of the Marshall Strawberry

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THE FORCING OF STRAWBERRIES

By FLORENCE I. KINNISON

The forcing of vegetables and some of the small fruits has a great future before it in Colorado. The climatic conditions, abundant sunshine and the dry atmosphere are great assets, as the crops will grow more rapidly, mature more uniformly, and there is a relative freedom from diseases and insect pests.

The cheapness of fuel is another item of importance in the economical production of the crop. At present, the forcing business is confined to the large cities, such as Denver, Colorado Springs, and Pueblo, where a good local market is obtainable. The industry in these cities is well established and is of sufficient magnitude to supply the local demand.

The forcing industry is necessarily restricted in its development by the lack of a wide local market, as the cost of transportation of perishable products makes it difficult for the growers to compete with other centers where the industry is more established and where the population is much greater.

However, little effort has been made to enlarge the market outside of Colorado for vegetables grown under glass, tho there is no reason why the Colorado growers should not compete successfully in many sections where the conditions for the growing of these crops are less favorable, and expensive.

While the forcing of vegetables is a relatively old industry and is well understood, the forcing of small fruits, especially strawberries, has not heretofore been undertaken, and little is as yet known of the commercial possibilities in this line.

In order to study cultural methods and to discover the best varieties for forcing, an experiment described in the following pages was planned and executed.

PLANTS FOR FORCING

The following varieties were used in the experiment: Warfield, Early Ozark, Senator Dunlap, Haverland, Bubach, William Belt, Marshall, Glen Mary, and Aroma.

The plants were selected from the first runners of mother plants which had been set out in the early spring. These runners were led over 5-inch pots which were plunged into the bed so that the rim of the pots were even with the soil. The soil in the

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pots consisted of one-third garden loam, one-third leaf mold, and one-third clean sand. Bone meal was added to this soil at the rate of 30 pounds to each 500 pounds of soil. Drainage was provided for by placing pieces of broken pots in the bottom of each pot. After the runners had become firmly established in the pots, they were detached from the mother plants. They were kept watered and in good growing condition until the middle of August when they were brought up to the greenhouses and shifted into 7-inch pots, after which they were placed in a coldframe and plunged into sand up to the rim. The same kind of soil, with the same fertilizer, was used as in the first potting. In the coldframe the plants were watered and the runners removed as soon as they appeared. The plants were in most excellent condition, and when freezing weather came, the coldframe was covered with a layer of leaves to protect the crowns from freezing and thawing during the early winter months. By this time, the pots were well filled with roots, and the crowns were large and plump.

To test whether the year-old plants were better for forcing than the young plants, a number of old plants were planted in pots at the same time that the runners were taken, and were treated exactly in the same manner as the young runner plants, but only two varieties of old plants were used, namely, Marshall and Glen Mary.

FORCING THE PLANTS

The pots were left in the coldframe until the latter part of January, having remained in a frozen condition during part of November, December and January. The plants were uncovered and the sun permitted to act on the coldframe until the pots could be loosened from the frozen bed; then they were taken into a cold cellar where the dead leaves and rubbish were removed, the pots washed and prepared for the greenhouse. They were left in the cold cellar for ten days to permit the soil to thaw out and to gradually start the root system into activity. The temperature of the cellar was from five to ten degrees F. above freezing. If they are removed to the greenhouse immediately after being taken out of the frozen soil, the crowns develop more rapidly than the root system, and the result is a poor crop and weak plants, while if left in a low temperature for a week or ten days the crown remains dormant while the root system starts its activity and is able to supply the plant food when the plant is placed in a higher temperature. Before final removal of the plants to the forcing house, each plant was thoroly sprayed with Bordeaux mixture to

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prevent the attack of fungous diseases. The plants were then moved into the forcing house and placed upon a bench. The different varieties were arranged in groups to vacilitate pollination and record-keeping. The temperature of the forcing house was kept at 40° to 50° F., the object being to develop a strong root system with a more gradual development of leaves. The bed on which the plants were placed had a layer of fine sand into which the pots were partially embedded. This prevented a rapid drying out of the plants and retained the moisture, which is an important element in our dry atmosphere.

After two weeks, the temperature of the house was raised from 50° to 65° F., and the plants began to show signs of putting out flower stems. At this time, it is important that the greenhouse be kept relatively dry to insure a more perfect pollenization.

POLLINATION

When the flowers were ready to be pollinated, the temperature was raised to 70° and 75° F., and kept at this temperature as nearly as possible for the balance of the flowering period. Pollenization began March 8 and was completed March 15. During this time we had a bright sunshine and practically no cloudiness, which resulted in perfect setting of the fruit. The process of pollination is the most important thing in raising a perfect crop. If this is not done carefully and thoroughly, lop-sided and knobby berries result. Each pistil has to receive a pollen. The pollen were first collected in a watch glass by the use of a fine camelhair brush, and then transferred from the glass, by the aid of the brush, to the pistillate flowers. The operation was performed during the middle of the day, from ten o'clock, a. m., until two or three o'clock in the afternoon. The pollination was aided considerably by the presence of a large number of bees which gained an entrance to the greenhouse thru the ventilator. The pollination was continued every day until every blossom had been pollinated several times. After this work has been accomplished, the thinning of the fruit set is important. The individual plant will set more fruit than it can properly mature without sacrificing size and appearance. For this reason, each plant was limited to 8 or 12 fruits, the number depending upon the vigor of the plant.

THE FEEDING OF THE PLANTS

After the fruit was well set, the feeding of the plants began. This is the most critical period in forcing strawberries, as there is considerable danger from disease and insect attacks. The watering must not be overdone, yet the plants should not suffer

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from lack of water. The red spider is the worst pest to contend with in forcing strawberries. It is prevented by frequent sprinkling of water on the leaves, previous to flowering to have the leaves as free as possible from this insect, as, during the flowering period little or no sprinkling can be done without injury to the process of pollination.

In this experiment, the red spider was entirely eliminated by the early treatment and did not interfere with the progress of the work. The plants were given a dressing of bone meal at the rate of one-half ounce to each plant. It was worked into the soil. In addition, one application of liquid manure was made, also an application of nitrate of soda in liquid form at the rate of 2 grams to 100 c. c. of water. This constituted the fertilizers applied to the plants after the fruit was set. Too heavy application of fertilizers at this time is apt to produce tasteless fruit, and fruit too soft for handling.

FRUITING PERIOD

The development of the fruit and the coloring was very rapid, as the weather conditions were exceptionally favorable.

It is important that the forcing house be kept dry during the ripening period. The flavor, as well as the keeping quality of the berries are impaired by too much moisture.

To keep the fruit clean and above the soil in the pots, screens made out of wire gauze or netting were used. The netting was cut into squares and a slit made from the edge to the center of the pieces, and these slipped around the crown of the plants, covering the top of the pot completely. This gave a clean place for the berries to rest upon.

By keeping the temperature and moisture conditions in the forcing house even, the crop ripened very uniformly, and there was very little difference in the time of ripening of the different varieties in the experiment. The time that intervened between the ripening of the first berries and the last, was 14 days.

HARVESTING THE BERRIES

While the ripening process was fairly uniform, several pickings were necessary. The fruits were clipped off, leaving about one-half an inch of the stem adhering to the berry. Half-pint raspberry boxes were used and a few green leaves placed with the berries to make them attractive. The fruits should not be handled, except by the stem. Ready sales were found at twenty-five cents per half-pint box.

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YIELD OF DIFFERENT VARIETIES

Number of Pots	Variety	Weight in Grams
10	Warfield	327
10	Early Ozark	647
10	Senator Dunlap	497
10	Haverland	633
20	Bubach	1000
23	Wm. Belt	740
50	Marshall (old and new crown)	2053
100	Glen Mary (old and new crown)	6064
10	Aroma	217

It will be noticed that Early Ozark gave the highest yield per pot; Haverland second highest; Glen Mary third; Marshall fourth; Senator Dunlap fifth; Bubach sixth; William Belt seventh; Warfield eighth, and Aroma ninth. Eliminating the old plants of the Marshall and Glen Mary from the total number, Glen Mary is the highest yielder in weight and marketable fruit, followed by Marshall. While the Early Ozark gave a high yield, the fruit was small, soft and of rather poor quality. The same was true of the Warfield. This variety bore the largest number of fruits, but the fruit is too small. Haverland gave a large yield, but the fruit was poorly colored and too soft for handling. Bubach gave a fine yield, but the fruit was somewhat irregular and not up to the standard. William Belt produces the largest berries, but this variety has a decided tendency to produce double fruit, and does not ripen evenly. Senator Dunlap produced fine fruit, but not of sufficient quantity. Aroma proved to be a very poor yielder, and gave the lowest results of all varieties. The old plants both of Marshall and Glen Mary produced small and inferior fruits. The vigor and general appearance of the plants were poor.

CONCLUSIONS

Marshall and Glen Mary proved to be the best two varieties for forcing in Colorado. The fruit produced is large, fine color, firm and of excellent quality. Marshall does not yield as heavily as the Glen Mary, but compensates for this deficiency by producing an extra high quality of fruit. The chief reason for using Marshall in forcing is because of its ability to produce an abundance of pollen, while Glen Mary produces few, if any.

New crowns are preferable to old ones, as they produce a heavier yield and larger and better berries.

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The secret of success in forcing strawberries depends upon the following points:

First.—Strong, vigorous plants.

Second.—Proper resting period, which should be about three months.

Third.—A dry, well-ventilated forcing house.

Fourth.—Slow starting of the plants to permit a strong development of the root system before the leaves expand.

Fifth.—Frequent sprinkling of the foliage previous to flowering to keep away the red spider.

Sixth.—Special care and thoroness in the pollination, to insure a perfect setting of fruit.

Seventh.—Carefulness in picking and packing.

Due to the shortness of time required for the crop of strawberries, the crop can be made a paying one at twenty-five cents per half-pint.

ACKNOWLEDGMENT

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Bulletin 223 February, 1917

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

A FRUIT SURVEY OF MESA COUNTY

BY

E. P. SANDSTEN, T. F. LIMBOCKER and R. A. McGINTY

A Birds-Eye View of a Peach Orchard Near Palisade, Colo.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
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A FRUIT SURVEY OF MESA COUNTY

BY

E. P. SANDSTEN, T. F. LIMBOCKER and R. A. McGINTY

Ten years ago, fruit growing in Grand Valley was very profitable. Peaches often netted the growers $1.25 per box, while apples and pears cleared $2.50 per box. It was like picking money off of the trees. The growers were getting rich and real estate men were in their glory. It was an easy matter to get easterners to buy fruit land at $1,000 or more per acre, for, as the real estate men pointed out, one year's crop might pay for the land. Hundreds of men from all walks of life invested their money in fruit land, speculation was rife, many companies were formed for planting orchards, and thousands of fruit trees were set out on land wholly unsuited for fruit growing. Bearing orchards were divided into five and ten-acre tracts and sold to persons, most of whom were inexperienced in fruit growing. Many of these new orchardists sat back in their easy chairs to watch the dollars grow. Others, uninitiated into the art of fruit growing, did not care for their crops as they should have done. As a result, the fruit became poorer in quality, and not being carefully graded, the demand for Colorado fruit became less. Prices continued to drop until, in the season of 1914, with an enormous crop all over the country as well as at home, most growers lost money on their fruit. Many carloads of fruit were shipped which did not pay for the freight. Thousands of bushels were allowed to drop and rot on the ground. The season of 1915 was a very hard one; with the exception of the immediate Palisade district, practically all of the Valley was frozen out. To make matters worse, prices were poor and very many growers had to give up their orchards. It was rightfully an exceedingly discouraged lot of orchardists which were visited by the writers in the summer and fall of 1915. Most of them were sick of the fruit business and wanted to quit. Some few, however, who had used good methods in growing and marketing their fruit were still making money.

It was with the idea of studying in the field the conditions prevailing there that this fruit survey of Mesa County was made.

EXTENT OF SURVEY

That part of Mesa County in which the fruit survey was made is the portion of Grand Valley which was irrigated previous to the opening of the Government ditch in 1915. It is about 32 miles in

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Apple Harvest in Grand Valley.

length and extends from about 2 miles above Palisade to an equal distance west of Loma. In width it varies from less than a mile at Palisade to about 5 miles at a point about midway between Clifton and Grand Junction. The total area of land within these limits is about 75,000 acres. The elevation of the Valley varies from 4,500 to about 4,800 feet. Nearly every orchard in the Valley was visited and the owner or tenant interviewed personally. Altogether about 1,800 places were listed.

PERCENTAGE OF LAND SET TO FRUIT WITHIN LIMITS OF SURVEY

Nearly all of the bearing orchards of the Valley, except on Orchard Mesa, southeast of Grand Junction, and a few scattering orchards, are planted north of the river. The percentage which is planted to fruit trees between the river and the highest irrigation canal on the north is, approximately, 70% in the Palisade District, 56% in the Clifton District, 20% in the Grand Junction District, 12% in the Fruita District, and 13% in the Loma District. The

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Orchard Mesa and Redlands Mesa orchards are, except those mentioned, young, and most of them have never borne. On account of the uncertainty of irrigation water, many of them have been neglected and are in poor condition.

TIME OCCUPIED IN SURVEY

The field work of this survey was begun early in the summer of 1915 and finished late in the fall. The data were carefully worked up at the Agricultural College in Fort Collins during the winter. Due to the enforced absence of the junior author during the summer of 1916, the publication of the results was delayed several months.

METHODS USED IN SURVEY

In order to get detailed information in regard to the situation in Mesa County, very complete blank forms were prepared for use in the survey. See Page 6 for reproduction of this form. The fruit growers were visited personally and the information received from them recorded on the blanks. Care was taken to get accurate answers to the questions asked. The blanks were filed away in order until ready for tabulation. In working up the notes, caution was used to put the orchards in their proper sections. Thus it was possible to determine with a fair degree of accuracy the acreage and kinds of orchards located in each section of the Valley. The trees were divided into age classes, to show approximately their state of production. The four classes used were, six years and under, classed as non-bearing trees; seven to ten years, eleven to fifteen years, and sixteen years or over.

For convenience, the Valley was divided into five districts by the range lines, and each named after the town located in it. That part of the Valley lying east of the range line which runs about one and a half miles east of Clifton, is called the Palisade District. That in Range 1 East, or lying between the aforesaid range line and that running just west of the Teller School of Agriculture and Mechanic Arts, about one mile east of Grand Junction, is called the Clifton District. The Grand Junction District comprises that land in Range 1 West and extends westward from the above range line to that lying just west of the Ute switch of the Denver & Rio Grande railroad. From this range line to that one mile west of Fruita is the Fruita District, and the fifth, or Loma District, extends from the latter range line to that just west of the town of Mack. The northern and southern limits of these districts are marked by the highest irrigation system on the north and south sides of the river. These districts are clearly shown on the map.

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Fruit Survey of Mesa County, Colorado

T._____R._____Sec._____Lot_____

No. of acres in fruit..... No. of trees..... Distance to Station.....

SOIL S. Loam.... Clay.... Silt.... Adobe.... Distance to water table....

APPLES

No. of acres..... No. of trees..... Age of trees..... Condition of trees.....

Variety..... No..... Var..... No..... Var..... No..... Var..... No.....

Variety..... No..... Var..... No..... Var..... No..... Var..... No.....

Variety..... No..... Var..... No..... Var..... No..... Var..... No.....

PEARS

No. of acres..... No. of trees..... Age of trees..... Condition of trees.....

Variety..... No..... Var..... No..... Var..... No..... Var..... No.....

PEACHES

No. of acres..... No. of trees..... Age of trees..... Condition of trees.....

Variety..... No..... Var..... No..... Var..... No..... Var..... No.....

PLUMS

No. of acres..... No. of trees..... Age of trees..... Condition of trees.....

Variety..... No..... Var..... No..... Var..... No..... Var..... No.....

APRICOTS

No. of acres..... No. of trees..... Age of trees..... Condition of trees.....

Variety..... No..... Var..... No..... Var..... No..... Var..... No.....

CHERRY (Sour)

No. of acres..... No. of trees..... Age of trees..... Condition of trees.....

Variety..... No..... Var..... No..... Var..... No..... Var..... No.....

CHERRY (Sweet)

No. of acres..... No. of trees..... Age of trees..... Condition of trees.....

Clean culture..... Cover crops..... No. of irrigations.....

Cost of Prod. per box,—Apples... Pears... Plums... Cherry (So)... (Sw)...

Acreage increased or decreased,—Apple... Pear... Peach... Plum... Cherry..

Is fruit growing profitable?..... Which fruit?.....

SPRAYING

No. of times,—Apples..... Pears..... Peaches..... Plums..... Cherries.....

How much poison per 100 gal. of water..... Does it pay?.....

Cost of spraying..... Per cent clean fruit.....

Would special or general farming be profitable with fruit growing?.....

What can C. A. C. do to aid the fruit industry?.....

Remarks:.....

.....

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The data for these districts are given separately throughout the bulletin for comparison.

After the data were compiled, such increases to the total acreage, total number of trees, etc., were made as were deemed necessary to allow for orchards missed. These varied from 1% to 4½% and are fairly accurate. The figures as listed in the tables are, we believe, as nearly correct as it is possible to make them.

Only the more important of the data collected are given in the bulletin. For instance, of more than 100 varieties of apples, only six are discussed and 21 others mentioned. Many varieties, especially of apricots, plums and cherries, were unknown and were so listed.

TOPOGRAPHY

In general, the Valley is quite level. In fact, portions are too level for good drainage. It slopes westward with the direction of the river, from the north, southward to the river, and on the south side, northward to the river. While the Valley is level, there are found in many places ridges and depressions, the former containing a loamy soil excellent for fruit, and on which are found some of the finest orchards in the Valley. The lower places generally become seep holes under irrigation, as water collects from the higher adjacent lands. On the whole, the Valley possesses natural conditions for adequate drainage, when developed.

CLIMATIC CONDITIONS

The Grand Valley, being located on the western slope of the main range of the Rockies, enjoys a milder climate than a similar location and elevation on the eastern slope, and, as a consequence, the Valley produces a great variety of fruit to perfection. The annual rainfall is less than on the eastern slope, being only 7 or 8 inches per annum. This small rainfall makes irrigation an important factor in fruit growing. While the climatic conditions are favorable for the growth of all standard varieties of temperate zone fruits, the occurrence of belated spring frost makes for a short crop year now and then.

On the whole, it can be said that the Valley is very well adapted for commercial fruit growing from a climatic point of view.

SOIL

The soil of Grand Valley is of a silt formation, rather heavy in texture, approaching the adobe type. A few ridges and a small district adjoining the river are more sandy and loamy, but in general the soil is heavy and not easily managed. While the soil of

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Grand Valley is well adapted to the different kinds of fruit, local soil problems have arisen that need special attention from the growers. The most important problem is that of niter accumulating in the orchard soils. For a technical discussion of this problem, see Bulletin No. 193 of the Colorado Experiment Station.

A full discussion of the niter problem from the orchardist's point of view will be given under the head of "cover crops."

DRAINAGE

While the natural drainage of the Valley is good, yet, due to liberal irrigation, much of the land occupying somewhat depressed portions of the Valley is suffering from seepage and standing water. The water-table, on the whole, for a considerable portion of the Valley has been raised to within 10 feet of the surface, and in some parts of the fruit sections it is less than 5 feet from the surface. This raising of the water-table has a decided influence upon commercial fruit growing in the Valley, but the difficulty bids fair to be eliminated by a system of drainage to be installed through the whole length of the Valley.

ALKALI

Like most irrigated sections, the Grand Valley has a considerable acreage of what might be termed alkali land. These alkali areas are not uniformly distributed, but occur in different sections, especially where there has been a large amount of seepage water, which upon evaporation deposits the alkali on the surface. These alkali areas are particularly noticeable east and west of Grand Junction and on the low-lying land close to the river. Many of these alkali areas are unsuited for fruit growing, and some of them are so heavily impregnated with alkali as to make them useless for all agricultural purposes. Undoubtedly the larger portion of these alkali lands could be reclaimed by heavy washing, if sufficient drainage is provided for them. The alkalis are all white ones, ex-drainage is provided for them. The alkalis are all white ones. Black alkalis or carbonates, so far as is known, do not occur in the Valley.

DISTANCE FROM STATION

For the purpose of learning the average distance fruit had to be hauled in shipping, the distance to the nearest shipping point was recorded. It was found that the average distance to the station for all orchards of the entire Valley was 1.55 miles. For the districts separately it was as follows: Palisade 1.2 miles, Clifton 1.25 miles, Grand Junction 1.8 miles, Fruita 1.85 miles. The shipping points used were Palisade, Bridges' Switch, Clifton, Fruit-

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vale, Grand Junction, Fruita and Loma on the D. & R. G. railroad, and Hollandville and Hunter stations on the electric railroad between Grand Junction and Fruita.

As this indicates, most of the farms are very close to loading points, doing away with the necessity of long hauls.

SIZE OF ORCHARDS

The survey reveals the fact that the average size of orchards in the Grand Valley is 8.8 acres; the average for Palisade is 7.0 acres, for Clifton 10.8 acres, Grand Junction 8.5 acres, Fruita 7.5 acres. The average size of orchards in the Loma district could not be obtained, due to the fact that most of the owners of orchards in this district are non-residents and their property is being attended by tenants who have often 100 acres in their care. It is estimated at 10 acres.

A majority of orchards are of 10 acres or less. Especially in the east end of the Valley are the orchards cut up into small tracts, some of less than 5 acres. It is hardly possible, except in the best of fruit years, to make a reasonable profit from 5 acres of land, when it is all planted to fruit trees, and a bad year is almost disastrous. The necessity of re-adjusting the land to increase the size of farms seems imperative. With the return of reasonable land values, this re-adjustment is practicable.

IRRIGATION

The problem of irrigation has been a big one. Water has, as a rule, been plentiful and the growers have used entirely too much. The tendency with many has been to let irrigation take the place of cultivation. This has resulted in leaching out of the soluble plant food and puddling the soil so that it bakes and is hard to work. Then, too, it has raised the water-table in many places so close to the surface of the soil that it is impossible for trees to live.

As a general thing, the farmers have irrigated lightly and very frequently, instead of giving thorough irrigations at less frequent intervals. The latter plan results in soaking the ground to a good depth and when followed by cultivaton holds the moisture for a long time. It does not puddle the soil, causing it to bake, but accomplishes the desired purpose of supplying plenty of water for the trees better than lighter irrigations.

The statistics gathered show five or six irrigations to be the average number applied for fruit crops. The growers in the Palisade District irrigate somewhat oftener than those in the western part of the Valley. There is also more land under clean cultivation in this district than in cover crops. There are several seepage

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Irrigating Scene in the Grand Valley.

areas in the Valley caused from over-irrigation and poor drainage. In many of these, it is impossible to grow anything, and some of them will mire a horse. Many once profitable orchards have been utterly ruined by seepage, and a good many more are doomed unless the needless over-irrigation is discontinued.

The water for irrigation is taken from the Grand River some distance above the main Valley. Naturally, the lower land or the land adjacent to the river was first developed, due to the cheapness in constructing irrigation canals. The upper lands closer to the foothills at Palisade and south of the river are irrigated by water from pumping plants, making the irrigation expensive. The new government project which was completed last year opens up an extensive area of land above the old canals. This will have a considerable bearing upon the land under the old irrigation system. Water is abundant, and, with the exception of that supplied by pumping plants, is cheap.

COVER CROPS

The use of cover crops in the Grand Valley is of relatively recent date. Clean culture has been the universal practice throughout the district. With the appearance of the niter troubles and with the gradual burning out of vegetable matter in the soil in many orchards, the decline of trees has been very rapid. A num-

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A Peach Orchard at Palisade Showing Methods of Furrow Irrigation.

ber of growers early realized the necessity for a more rational system of culture and are seeding their orchards to some kind of crop that can be plowed under, thus adding the necessary humus to the land.

Alfalfa has been the favorite cover crop in the orchards, but this crop has several drawbacks, the main one being that it is difficult to eradicate after it has been once established. A cover crop should not be kept in the orchard for more than two or three years, after which clean culture should be practiced for an equal period. In other words, a cover crop and clean culture should alternate if the best results are to be obtained.

Medium red clover is used by a number of growers with very satisfactory results. The first crop can be cut and either used for hay or left as a mulch on the ground, the second crop being left uncut, which will help to hold the snow and moisture in the winter. The second year the same method may be pursued except that the second crop should be plowed under, leaving the orchard to be

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clean cultivated. Where it is difficult to obtain a stand of clover, oats may be used, but it should be plowed under and not cut for hay. After this has been done for one or two years, it is generally easy to obtain a good stand of clover.

Hairy vetch gives promise of becoming an important cover crop in Grand Valley. This is a biennial plant that should be sown in September and plowed under the following May. It starts to grow in the fall, stands the winter well and makes a heavy mat of green herbage by the last week in May.

An Apple Orchard in Cover Crop of Red Clover, Grand Valley, Colorado.

The use of cover crops has proven beneficial to the orchards in the Grand Valley and the practice should be extended to every orchard. When cover crops are grown, they should be left on the ground to plow under, as hay and fruit cannot both be grown on the same land successfully.

The practice of dividing the orchard into several parts by fences and allowing hogs to run alternately in each gives promise of success where alfalfa or clover are used as cover crops. This permits moving the hogs from one part of the orchard to another when irrigating. The hogs eat up the culls and fallen fruit as well as the cover crop, and their manure is left on the ground, thus adding to the fertility of the soil. This practice is not recommended for orchards in which the trees are small and easily injured by the rubbing and rooting of the animals.

The most serious soil problem in Grand Valley is niter. The presence of a large amount of niter was noticed several years ago

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by Dr. Headden and later by Professor Sackett of this station, and these gentlemen have carried on extensive experiments to discover the cause or origin of the niter. These experimentors have clearly proven that the presence and accumulation of the niter in the Grand Valley is of a bacterial origin. The accumulation of niter is much more rapid on lands under a clean culture system, and consequently the orchards were first to suffer from this trouble. In some cases the niter has accumulated to the extent that all vegetation has been killed and the land left entirely barren and unproductive. A considerable percentage of the older orchards were killed and the land left barren through niter accumulations.

The Horticultural Department, about three years ago, undertook to carry on some experiments with the view of eliminating or neutralizing the effect of the niter and making the land produce a normal crop. The results of these experiments show that the niter problem can be handled by the use of cover crops which will protect the land during the summer and by the effect upon the soil of turning under the green materials grown. This method is effective and should be practiced by fruit growers whose orchards are not as yet suffering to any extent from niter trouble. Where the land has gone so bad as to become barren, the only method known by which it can be reclaimed is by washing the soil. The nitrates being soluble in water can easily be washed out by heavy flooding or heavy irrigation. This method was tried on a piece of land that was entirely barren and in two years the land was entirely reclaimed and produced normal crops. This washing or flooding of the land calls for drainage to carry off the surplus water. It also requires that the land should have at least a gentle slope to permit the water to run off freely. This method of reclaiming niter land is not applicable to land in growing orchards. The cover crop method is the only safe and rational way of overcoming niter accumulation, and it is a rational method of orchard management that every intelligent fruit grower should follow. In other words, the niter problem should not occur if rational methods of orchard management are followed out.

COST OF SPRAYING

The mean of 34 estimates on the cost of spraying per 200 gallon tank is $2.05. For the cost per acre per season of arsenical sprays, 41 estimates gave an average of $20.00. This, divided by 5.85 (the average number of sprays per season for apples for the Valley), gives $3.40, or the average cost per acre for one applica-

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tion of arsenical spray. The cost per spray of lime-sulphur, the mean of 95 estimates, is $6.65 per acre.

There was much variation in the answers given for the spraying data. Many of the orchardists have absolutely no idea of the cost of this work.

INCREASE AND DECREASE OF ACREAGE

The past five years have seen considerable decrease in the acreage of orchards in the Grand Valley. It is safe to say that during this period at least 2,500 acres of orchards have been pulled out. Various reasons are assigned for the removal of the trees, chief among them being poor prices, seepage and neglect.

The decrease in acreage has affected the apples most severely, and the loss has been heavier in the older districts. The following estimates, based on actual figures, give an idea of the amount of orchard pulled out between 1911 and 1915. These estimates are, probably, in most cases, low. Palisade shows a decrease of about 150 acres of peaches and an increase of 50 acres of apples and 75 acres of pears. The Clifton District has lost 400 acres of apples and 450 acres of peaches, the acreage of pears remaining about the same. In the Grand Junction District the acreage has been diminished by 600 acres of apples, 150 of pears, and 50 of peaches. Fruita shows a loss of 750 acres of apples, and Loma has a decrease of 100 acres of apples.

In some few cases, good bearing orchards have been pulled out, but in most cases it was better that the trees were removed. The Valley as a whole would be vastly improved if all the ill-planted, seeped, neglected or otherwise unprofitable fruit trees were removed and a lot of inferior fruit thus kept off the market.

Fruit growing, like all other agricultural industries, thrives best only under favorable conditions. One cannot profit from an orchard under adverse conditions. When it is seen that fruit trees will never yield a fair return, they should be taken out and the land devoted to other crops.

YIELD

For the years 1911 to 1915, the average number of acres of bearing orchard was about as follows: Apples, 6,000; pears, 1,100; peaches, 1,800. Assuming that 90% of the fruit grown during this period was shipped out of the Valley, the average yield for the Valley would be about 800,000 boxes of apples, 60,000 boxes of pears, and 1,150,000 boxes of peaches. This would give an average yield per acre of about 135 boxes of apples, 145 boxes of pears, and 640 boxes of peaches.

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It is absolutely impossible to obtain accurate figures on the number of acres of bearing orchard or the yield per acre. No claim of authenticity is made for these data on yields. Yet, though they are merely estimates, they give some idea as to the probable yields and are as nearly correct as can be determined from the data at hand.

THE COST OF PRODUCTION

One of the questions asked the growers was the cost of production per box of the different fruits. Many of them had absolutely no idea of the cost, and others had pretty close figures on this. While there is considerable variation in the estimates given, the mean is no doubt very close to the actual cost of the fruit. The averages of the estimates for the cost of fruit f. o. b. their shipping point, including all expenses, was as follows: Apples, 61.2c per box (the average of 61 estimates ranging from 40c to 86c); pears, 60.5c (average of 37 estimates, varying from 40c to $1.00); peaches, 31.2c (average of 78 estimates, varying from 20c to 43c).

It is quite evident that the growers must receive at least 65c per box net for apples and pears in order to make interest on their investment. At an average of $1.00 per box a fair profit can be made. At this price they should reach the consumer at $1.50 to $2.00 per box, which is not too much to pay for first-class fruit.

Peaches should net 40c to 50c per box, making them retail at $1.00 to $1.25 per box.

MARKETING

The greatest trouble the fruit growers have to contend with is the marketing problem. This has, for several years, been causing unlimited trouble. Numerous methods of selling fruit have been tried and, without exception, all have been found wanting. Experience has proved that co-operative selling associations offer the most satisfactory solution to the problem. This system of co-operative selling originated in Grand Valley and has been tried here a number of times, but with varying degrees of success. When fruit was bringing good prices things went all right, but with the drop in price, trouble brewed.

There is one big defect in the system—the average farmer will not co-operate. Whenever he sees a chance to get a little more for his fruit than he is getting through the association, he will do so, regardless as to what happens to his associates. It is to this failing that the success of unscrupulous commission agents is due. The plan of these men is to promise the farmers a little more for their fruit than their associates are getting for it. The farmers usually let the agent take their fruit. If they are too skeptical

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and hesitate to leave the association, the agents advance a certain amount per box on the fruit, the balance to be paid when the fruit is sold. There are many instances in which the growers never hear from the agent again; in others, where they receive a bill for the freight, and still others where money has been advanced for the fruit, they get a bill for a refund on the payment advanced. This they are often compelled to pay.

The strangest thing of all is that often the very men who are defrauded in this way are "taken in" again the next year. It is easy to see that under these conditions a co-operative association cannot be successful.

The consignment system has not proved very satisfactory. In any carload of fruit not strictly graded, there will be boxes which are below standard. The commission men, finding this, refuse to handle the consignment, except at a lower grade. Oftentimes consignments are reported in bad condition when they are as good as represented. The owners must either allow the fruit to be marked down or turn it over to someone else. This is not very easy to do when they are several hundred miles away. Sales on an f. o. b.

Modern Method of Transportation. The Apple Crop is Handled by Interurban Electric System which Connects with the Railroad.

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basis would do away with this practice. Even where commission men are honest, there is much complaint. Fruit is often not up to the standard, and when the market is full, as it frequently is, they cannot sell the fruit at good prices. The commission man then gets the blame for poor prices and is accused of dishonesty.

Many growers have tried the plan of selling their fruit direct, or of shipping it to some town and selling it from the car. There have been varying degrees of success with this system of selling. Some men have netted good returns from it, while others failed utterly. Altogether, the plan is not satisfactory.

Yielding to the pressure from many growers, the Grand Junction association tried out the plan of sending men to the more important middle western markets and shipped fruit to them for distribution. The belief, held by many orchardists, was that these men could watch the market more closely and hence dispose of the fruit to much better advantage than the association manager in Grand Junction. The plan fell far short of the expectation of its advocates and was declared by the association to be a failure.

The ultimate solution of the marketing problem will in all probability be a more closely co-operative association through which the members alone may ship their fruit without extra charges. The members must agree to sell all of their crop through the association, and any fruit growers who are not members must pay considerably more for having their products marketed by the organization.

Another factor which would doubtless work a benefit in marketing would be the establishment of community packing houses. These would be located in the most accessible places and would be sufficiently numerous to take care of all the growers without delay or long hauls. These packing houses would be under the direct supervision of the association representatives who would see that all growers received fair and impartial treatment and that the fruit was strictly graded and carefully packed. This would insure uniform packages and facilitate f. o. b. sales.

Besides, with the work carefuly done, the association would gain a reputation for good fruit and the fruit would largely sell itself on its own name. Under the present system, every man packs his own fruit and there is little uniformity in the packages. Such lack of conformity leads dealers to distrust the quality of produce in any grade, and hence refrain from buying except on consignment.

The shipping of standards, or fruit below the second grade, has worked a great detriment to the fruit industry. It would be

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far better not to ship this fruit at all, as it competes with the better grades on the markets.

The shipping of second-grade fruit in baskets will most likely become more popular with the growers in the future, as it affords a cheaper method of putting up the fruit, and the baskets themselves are much more useful to the ordinary consumer than the boxes. This should be especially true with apples and pears. Another advantage in marketing in baskets is that the consumer can see the quality of the product he is getting and it sells itself on sight more often than when packed in boxes.

FARM EFFICIENCY

There are very few fruit growers in Mesa County who keep any kind of records of their transactions. Thus it is almost impossible for them to know where they are gaining or losing money, what the different operations cost, or where they could save money.

Neither do most growers follow any system in their work, but go at their work blindly, often doing things several times where one time properly done would suffice. The men who have been making money during the low-price period have, in nearly all cases, been men who study their business and keep a set of books to show where they stand financially. They are also usually men who are ready to listen to suggestions for improvement in their methods.

It is very important that a set of books be kept and a system worked out which will give the greatest possible efficiency. The aim should be to avoid all waste, and arrange the work so that it will not conflict and so that there will be always something to do. This will materially add to the profits of the farm.

DIVERSIFICATION

The question of diversified farming arises in connection with fruit growing, especially in view of the recent poor years for fruit. The majority of farmers in the Valley, when interviewed, were of the opinion that diversification would pay in connection with fruit growing. With land at its present prices and cut up in tracts of ten acres or less, diversified farming is hardly practicable. However, there is little doubt that with 20 acres or more the vast majority of growers would benefit by diversifying.

There are a few of the best fruit growers who can always make more money with fruit than anything else. These men are the exception and not the rule. Every grower should at least have a cow, a few pigs and chickens, and a small garden patch. The first cutting of alfalfa or clover may be used for hay where there is a good stand in the orchard, but no more should be taken. Many

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farmers have tried the growing of special crops such as canteloupes and small fruits, and some of them have been very successful in this venture.

Regarding the Valley as a whole, there are too many men in the orchard business who are not fruit growers, and too many tracts of fruit trees which are not orchards in a real sense, for the business to thrive except under extraordinary conditions.

More land devoted to alfalfa, sugar beets, grain, and stock and less to fruit growing, would undoubtedly mean better success for most of the Grand Valley farmers.

SMUDGING
(Orchard Heating)

The concensus of opinion among orchardists in Mesa County is that the attempt to ward off frosts by smudging (building fires in the orchard to raise the temperature) is not a paying proposition. Practically all systems of smudging have been tried with varied results, but the practice has been abandoned by most of the growers.

The trouble is that the conditions must be very favorable for effective smudging. At best, the temperature can be raised only a few degrees and when the frost is accompanied by a wind, it is almost impossible to do any good. As a safeguard, many nights of wearisome toil are often spent in smudging, only to find that the frost was not hard enough to do any appreciable damage. Under any conditions, smudging is a very disagreeable, man-killing task, as well as being expensive. When one spends several nights in smudging only to be caught by a late frost, or to find that his neighbors who did not smudge have as much fruit as he, he very seriously questions the utility of the practice.

Disregarding all worry and hard work, it is doubtful whether orchard heating is profitable. If one is not situated where fruit growing is fairly safe without smudging, the advisability of the business is exceedingly questionable. One had better either raise other crops, or move to a safe fruit-growing country. There are too many precautions that must be taken to successfully grow fruit in any district without adding that of constant danger from frost.

The continuance of smudging in commercial fruit growing will very likely be limited to vicinities where there are infrequent killing frosts and to the larger orchards. As a general practice, it appears to be a thing of the past.

TREE GROWTH IN THE GRAND VALLEY

The vigorous growth of fruit trees in the Valley indicates that the climatic and soil conditions are favorable for the development

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of sturdy and productive trees. The trees come into bearing early, and, with most varieties, large annual crops are produced.

The heavy wood growth makes the problem of proper pruning an important one, and this phase of fruit growing in the Valley has, in most cases, been given less attention than it deserves, for it is a well recognized principle in fruit growing that a tree, in order to produce the maximum crop of first-class fruit, must be reduced in wood growth so as to permit a free circulation of air and light through the tree and to produce fruit of sufficient size. If pruning is not systematically performed, the trees become too heavy in wood growth, which, in turn, will produce a large number of small, poorly colored fruits. In general, it should be said that fruit growing in the Grand Valley represents the advanced process in American fruit growing.

There is danger of neglect during a year of failure when the grower does not feel like spending money on the proper care of his orchard because there is no income. This is a mistaken practice, because it is universally recognized that no agricultural crop will suffer greater permanent injury from neglect than a fruit orchard. A few years of neglect will, in most cases, completely ruin the orchard and spoil it for future profitable crops.

SOME POINTS REVEALED BY THE SURVEY

The fruit survey shows that the development of the fruit industry in the Valley has been along logical lines, so far as the adaptation of the different kinds of fruit to the soil and climatic conditions is concerned. In the Palisade District, which occupies the upper end of the Valley, the peach industry predominates. This is natural because of the topography of this section. The Valley at this point is narrow and is shaped like a crescent, protected on the north and northeast by high bluffs, which retain the day's heat and make this part of the Valley practically frost-proof. The soil is of a sandy loam nature and admirably adapted for the growing of peaches, sour and sweet cherries and pears.

The Clifton District, immediately below Palisade, is the largest apple-producing section of the Valley. The Valley broadens out immediately after leaving Palisade, yet it is sufficiently close to the mountains to afford some protection against belated spring frosts. The soil bed is intermediate in character between a heavy adobe and loam, and is admirably adapted for the growing of apples. The topography of this section of the Valley provides for a better system of air and water drainage than sections below. The section immediately surrounding Clifton is planted almost solidly to fruit trees.

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The Grand Junction section occupies about the center of the Valley. This section is more uniformly level and suffers perhaps more from lack of drainage of both air and soil. Still there are several elevated portions of this section known locally as fruit ridges on which are located some of the finest orchards in the Valley. The soil in this section is, with the exception of the fruit ridges, heavy adobe and quite difficult of handling. The Fruita section follows the Grand Junction District in order westward. This section has a large acreage of sandy loam soil that is capable of producing a great variety of fruit, potatoes and vegetables, but, due to its position in the Valley, the orchards are subject to belated frosts which often cause the total or partial loss of a crop. A considerable portion of the low-lying land has suffered from lack of drainage. The Loma District occupies the most westerly portion of the Valley and is less developed. Although over 1,300 acres of orchard have been planted, the greater portion of it is in young trees. This section was mostly set out six to eight years ago during the boom period.

EXPLANATION OF MAP OF FRUIT BELT OF GRAND VALLEY

The map on Page 22 is designed to show the relative density of orchard in each square mile which contains over five acres of fruit land. This map is adapted from the United States Reclamation Service map of the Grand Valley Irrigation Project, and shows most of the land watered by the new Government canal, as well as by the older ditches. The various markings show how extensive the orchards are in each section.

The entire Palisade District north of the river is marked as being three-fourths orchard. It is possible that some sections of this district have not such a high per cent of orchard, but there is even a larger percentage of fruit land in most sections of this district.

There are a few sections which are left blank, but which should have been marked on the map. This is due to the fact that it was impossible to locate the orchard as to sections when the orchard itself was listed.

West of the Palisade District there is only one section which is over three-fourths orchard, and only one section west of the Clifton District is over one-half orchard.

EXPLANATION OF TABLES AND DIAGRAMS

For clearness and compactness, we have presented much data in the form of tables. In some instances, diagrams have been con-

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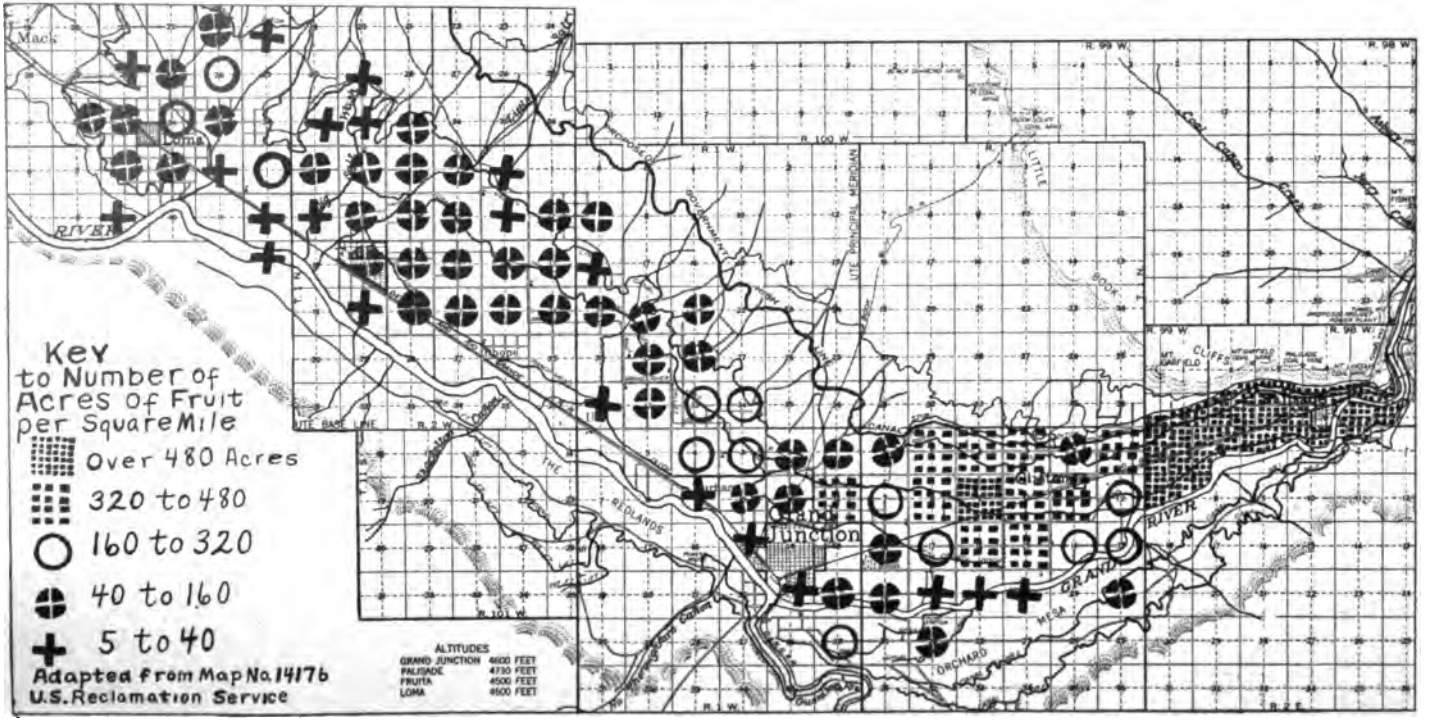

Map Showing Relative Density of Orchard in Each Square Mile Containing Over Five Acres of Fruit in Grand Valley.

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structed from the tables, showing graphically what the latter contain. These are very easily interpreted. Their method of construction is as follows: Suppose we want to show the number of fruit trees in each district of the Valley. Heavy perpendicular lines at regular intervals are chosen to represent the districts, these being arranged in order from left to right. Thus, the left line represents the Palisade District, the next one the Clifton District, etc. (See Diagram 1.) Next, horizontal lines are selected to represent the number of trees. The figures at the right of the sheet show the number represented. Referring, now, to Table I we find that the Palisade District contains 416,500 trees. (Total in right-hand column.) At a point on the left perpendicular equal to this number a mark is made. The same is done for the other districts, the mark on the second line being made at 578,625; the third at 217,350; the fourth at 150,575, and the fifth at 89,550. These points are then connected by a solid line which represents the total number of fruit trees in each district of the Valley. To represent the number of trees of each fruit the same method is used, the only difference being that different kinds of connecting lines are used, in order to be easily distinguishable from each other. A "key" is given on the diagrams to show what each line represents. In some cases, the lines are also lettered for greater facility of interpretation. By studying and comparing the tables and diagrams, much interesting information may be obtained. We have endeavored to present this information in the way easiest to comprehend.

CONTENTS OF TABLES AND DIAGRAMS

To prevent confusion, the diagrams are numbered the same as the tables from which they are constructed. There are, consequently, several numbers missing, as some tables have no diagrams corresponding to them.

Table I, Page 25.—This table shows the number of trees of the different fruits for each separate fruit district, and for the Valley as a whole; also the total number of fruit trees of all kinds for each district, and the total of all fruit trees in the Valley.

Table Ia.—An adaptation of Table I to show the percentage of all trees of each fruit contained in each district. The same is shown for the Valley as a unit. For example, we see that of the apple trees of the Valley, the Palisade District has 5.7%, the Clifton District, 47.2%, etc. Thus, it is clearly seen where any fruit is grown most extensively.

Table II, Page 26.—Shows the number of acres of orchards in each district in the Valley.

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Table IIa.—Shows the estimated number of acres of bearing orchards in each district.

Table III.—This shows the number of cars of fruit shipped from Grand Valley for each year from 1911 to 1915, inclusive.

Tables IIIa, IIIb, IIIc, and IIId give the number of cars of apples, pears, peaches and mixed fruits shipped from each town in Grand Valley for the years 1911 to 1915, inclusive.

Table IV.—This shows the six most important commercial apples of Mesa County, with their percentage of all apples grown for each district, also for the Valley as a whole.

Diagram 4. Same as Table IV.

Tables V, VI, VII, VIII and IX.—These tables give the principal varieties respectively of pears, peaches, plums, apricots and cherries for each district, and for the Valley as a whole. In the case of apricots and cherries, many varieties were unknown, and consequently, the percentage of fruits listed as "all others" is, in these cases, quite large.

Tables X, XI and XII.—These tables show the number of trees of apples, pears and peaches, respectively, in each of the fruit districts, separated into the age classes as defined on Page ..... From this we learn that the Clifton District has 196,000 apple trees from seven to ten years old, and only 46,000 over sixteen years old (Table X); that there are 20,300 pear trees in the Palisade District, and 47,750 in the Clifton District less than seven years old (Table XI); that the Palisade District contains 214,000 peach trees from seven to ten years old (Table XII).

Diagrams 10, 11 and 12.—Adapted from the above tables and show graphically what these tables contain.

Tables Xa, XIa and XIIa.—These tables are constructed from Tables X, XI and XII to show what part of all the trees of any age in the entire Valley are planted in each separate district. These are given in percentage form. Thus we see that 33.4% and 32.2% of the apple trees one to six years old are planted in the Clifton and Loma Districts, repectively, while only 6% are in the Palisade District, etc.

Tables Xb, XIb and XIIb.—By referring to these tables we may find what percent of the trees of any district are of any given age class. For example, from Table XIIb, it is found that 66.8% of all the peaches of the Valley were planted seven to ten years ago, when the fruit business was at its height.

Tables XIII, XIV and XV give the percentage of trees in each age class for plums, apricots and cherries and also show the total number of trees for each age class and for each district.

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TABLE I.—SHOWING NUMBER OF FRUIT TREES IN EACH DISTRICT.

District	Apples	Pears	Peaches	Plums	Apricots	Cherries	District Totals
Palisade	42,750	44,500	320,000	1,750	2,200	5,300	416,500
Clifton	354,000	149,500	69,000	2,150	800	3,175	578.625
Grand Junction	134,750	67,000	10,500	1,600	350	3,150	217,350
Fruita	129,750	13,600	5,400	500	250	1,075	150,575
Loma	88,750	400	100	....	....	300	89,550
Valley Totals..	750,000	275,000	405,000	6,000	3,600	13,000	1,452,600

TABLE Ia.—DISTRIBUTION (IN PERCENTAGES) OF TOTAL NUMBER OF TREES OF EACH FRUIT IN GRAND VALLEY BY DISTRICTS.

District	Apples	Pears	Peaches	Plums	Apricots	Cherries	Entire Valley
Palisade	5.7	16.2	79.0	29.2	61.0	40.8	28.6
Clifton	47.2	54.3	17.1	35.8	22.3	24.4	39.8
Grand Junction...	18.0	24.3	2.6	26.7	9.7	24.2	15.0
Fruita	17.3	5.0	1.3	8.3	7.0	8.3	10.4
Loma	11.8	0.2	....	....	....	2.3	6.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE Ib.—SHOWING RATIO IN PERCENT EACH FRUIT BEARS TO TOTAL NUMBER OF FALL FRUIT TREES FOR EACH DISTRICT.

District	Apples	Pears	Peaches	Plums	Apricots	Cherries	
Palisade	10.2	10.7	77.0	0.4	0.5	1.2	100.0
Clifton	61.2	25.9	11.8	0.4	0.1	0.6	100.0
Grand Junction...	62.2	30.9	4.8	0.7	...	1.4	100.0
Fruita	86.1	9.1	3.6	0.3	0.2	0.7	100.0
Loma	99.0	0.5	0.1	...	...	0.4	100.0
Entire Valley.....	51.5	19.0	28.0	0.4	0.2	0.9	100.0

INVENTORY OF FRUIT TREES

In making the survey, a careful record was kept regarding the number and varieties of all of the various fruits. These data, when compiled, gave the approximate number of each variety of fruit grown. The more important data are listed in tables, and by referring to them one may learn very nearly the position which these varieties hold in Grand Valley and each of the districts thereof.

As is shown in Tables I and II, there are 10,250 acres of apples comprising 750,000 trees; 2,400 acres of pears, or 275,000 trees; 3,000 acres of peaches, 405,000 trees; 190 acres of plums, apricots and cherries, comprising together, 22,600 trees. This gives a total for all fruits of 15,840 acres, or 1,452,600 trees. From this it may be seen that of the total number of fruit trees, 51.5 are apples, 19% pears, 28% peaches, 4% plums, 2% apricots, and 9% cherries. Approximately 75% of the apples, 70% of the pears, 90% of the peaches, and 90% of the plums, apricots and cherries are in bearing. Of all the trees listed in the Palisade District, 77% are peaches, 10.7% pears, 10.2% apples, and 2.1% other fruits (plums, apricots and cherries).

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The Clifton District has 61.2% apples, 25.9% pears, 11.8% peaches, and 1.1% other fruits.

TABLE II.—NUMBER OF ACRES OF ORCHARD FOR EACH DISTRICT IN GRAND VALLEY.

	Palisade	Clifton	Grand Jct.	Fruita	Loma	Valley Totals
Apples	520	4,515	2,010	1,855	1,350	10,250
Pears	350	1,260	650	136	4	2,400
Peaches	2,375	500	80	44	1	3,000
Plums, Cherries and Apricots	78	52	42	15	3	190
Totals, All Fruits	3,323	6,327	2,782	2,050	1,358	15,840

TABLE IIa.—NUMBER OF ACRES ORCHARD OF BEARING AGE FOR EACH DISTRICT.

	Palisade	Clifton	Grand Jct.	Fruita	Loma	Valley Totals
Apples	388	3,750	1,572	1,530	450	7,690
Pears	190	857	481	125	1—	1,654
Peaches	2,175	463	62	43	1—	2,744
Plums, Cherries and Apricots	66	47	47	10	3—	173
Totals, All Fruits	2,819	5,117	2,162	1,708	455	12,264

Grand Junction has 62.2% apples, 30.9% pears, 4.8% peaches, and 2.1% other fruits.

Fruita District has 86.1% apples, 9.1% pears, 3.6% peaches, and 1.2% other fruits.

In the Loma District, 99% of all the fruit trees are apples, .5% pears, .1% peaches, and .4% other fruits.

From Table Ia, it is seen that 79% of all the peaches grown in the Valley are in the Palisade District, 54.3% of the pear trees, and 47.2% of the apple trees are in the Clifton District. The table also shows the Clifton District to contain 39.8% and the Palisade District 28.6% of all the fruit trees in the Valley.

TABLE III.—NUMBER CARS OF FRUIT SHIPPED BY FREIGHT FROM GRAND VALLEY FOR YEARS 1911 TO 1915 INCLUSIVE.

	1911	1912	1913	1914	1915	5-Year Total
Apples	1,253	1,627	813	2,622	145	6,460
Pears	212	314	228	519	55	1,328
Peaches	149	1,336	856	1,302	744	4,387
Mixed Fruits	36	86	89	121	46	378
Valley Totals, All Fruits	1,650	3,363	1,986	4,564	990	12,553

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NUMBER CARS OF FRUIT SHIPPED FROM GRAND VALLEY FOR YEARS 1911 TO 1915 INCLUSIVE AND NUMBER FROM EACH SHIPPING POINT.

TABLE IIIa.—APPLES.

	1911	1912	1913	1914	1915	5-Year Total
Palisade	138	73	117	117	51	496
Clifton	258	405	226	861	30	1,780
Grand Junction	645	760	412	1,307	64	3,188
Fruita	212	389	58	336	...	995
Loma	...	...	...	1	...	1
Valley Totals, by Years	1,253	1,627	813	2,622	145	6,460

TABLE IIIb.—PEARS.

	1911	1912	1913	1914	1915	5-Year Total
Palisade	19	22	36	36	24	137
Clifton	56	97	74	198	6	431
Grand Junction	137	193	118	285	25	758
Fruita	...	2	...	...	...	2
Valley Totals, by Years	212	314	228	519	55	1,328

TABLE IIIc.—PEACHES.

	1911	1912	1913	1914	1915	5-Year Total
Palisade	138	989	851	1,091	733	3,802
Clifton	10	215	3	168	...	396
Grand Junction	1	131	2	43	11	188
Fruita	...	1	...	...	...	
Valley Totals, by Years	149	1,336	856	1,302	744	4,387

TABLE IIId.—MIXED FRUITS.

	1911	1912	1913	1914	1915	5-Year Total
Palisade	17	25	81	58	45	226
Clifton	...	25	2	34	...	61
Grand Junction	19	36	6	29	1	91
Valley Totals, by Years	36	86	89	121	46	378
Valley Totals by Yrs., All Fruits	1,650	3,363	1,986	4,564	990	12,553

APPLES

The apple has been grown commercially in Grand Valley for only about 25 years, although much of the Valley is especially adapted to its culture. It was here that Colorado apples first came into prominence, and this section of the country was one of the first to adopt the box pack for apples. The fruit developed wonderfully and so far surpassed eastern fruit that the sale for it was practically unlimited. The prices obtained were very good, and the pioneer apple growers reaped rich returns for a few years.

Soon there was a mad rush into the business. All kinds of trees were planted under all kinds of conditions. Nurserymen sold badly mixed up lots of trees, and the result was that over 150 varieties were grown in the Valley. There are still over 100 varie-

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ties grown, but only ten varieties which include over 1% each of the apples. They are, in order of importance, Jonathan, Winesap, Gano, Ben Davis, Missouri Pippin, Rome Beauty, Arkansas (Mammoth Blacktwig), White Winter Pearmain, York Imperial, and Delicious. The first six of these comprise 85.7% of the total trees planted. Table IV and Diagram 4 show the percentage of each of these varieties in each district and in the Valley as a whole. Note that there are three varieties which have a larger percentage than the miscellaneous varieties (over 100 in all), which are listed as "All Others."

The Jonathan is by far the most important apple grown. Over one-fourth of all the annual output is of this variety. The Jonathan is a fall variety, ripening in September, and is a splendid dessert apple. It thrives well under a variety of conditions, and is usually an annual bearer. The demand for this apple is always good.

The Winesap is second in rank. It is a greenish-red winter apple with a spicy flavor and is a general favorite with most persons. It seldom attains good size, but bears very heavily.

Gano is rapidly replacing Ben Davis, of which it is a seedling. It resembles the Ben Davis very much in appearance but is solid red, instead of being striped. It has a somewhat better flavor than the Ben Davis, and, like this apple, is a splendid keeper, often holding up well until the early summer apples come on. It is rather inferior in quality, but is very much in demand in southern

A Perfect Apple Orchard Twenty-five Years Old in Grand Valley.

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and Mississippi Valley markets. Gano will grow on almost any apple soils, but attains better color on the well-drained loams. Grand Valley grows this apple to perfection.

Ben Davis was originally grown more than any other variety in Grand Valley. There are still a great many bearing trees, but they are mostly old ones. In the Grand Junction and Fruita Districts there are a great many acres of Ben Davis trees. In the younger plantings, however, it is usually supplanted by Gano. Ben Davis is poor in quality and its chief virtue lies in its hardiness, growth habit, productiveness and keeping qualities.

Missouri Pippin is used very extensively for fillers. It is a small, slow-growing tree, very prolific and a regular bearer. It is grown most extensively in the Clifton District. The fruit itself is usually small, of a greenish-red or often dark-red color, with prominent white dots. The quality is rather poor, but the apple is well adapted for storage purposes.

Rome Beauty ranks sixth in order of percentage. It is one of Colorado's best apples. The fruit is usually of good size, yellowish-red or light red in color, with fairly conspicuous dots. The quality is good, but the texture of flesh is somewhat coarse. The apple is a good shipper and keeps well. It has a ready sale in the better markets.

The following varieties are sufficiently numerous to comprise between .1% and 1% of trees planted, named in order of importance: Stayman, Black Ben, Grimes, Minkler, Spitzenburg, Arkansas Black, McIntosh, King David, Winter Banana, Shackleford, Geniton, Wealthy, Champion, Lawver, Senator, Yellow Transparent, and Willow Twig.

The best early varieties for the Valley are Yellow Transparent and Wealthy. Yellow Transparent ripens late in July, and the Wealthy in the early part of September. These are both splendid apples, but are not much grown commercially, as the market for early apples is limited.

TABLE IV.—SIX PRINCIPAL VARIETIES OF APPLES, SHOWING PERCENTAGES GROWN IN EACH DISTRICT AND IN ENTIRE VALLEY.

Variety	Palisade	Clifton	Grand Jct.	Fruita	Loma	Entire Valley
Jonathan	31.0	27.0	24.0	27.0	23.4	26.5
Winesap	15.7	21.0	16.2	12.2	22.6	18.7
Gano	8.1	16.8	17.6	22.3	17.4	17.5
Ben Davis	11.6	9.5	12.6	14.8	0.9	10.1
Missouri Pippin	7.5	9.5	4.5	5.0	8.9	7.6
Rome Beauty	4.9	4.2	5.0	2.2	15.1	5.3
All Others (over 100 varieties)	21.2.	12.0	20.1	16.5	11.7	14.3
Totals	100.0	100.0	100.0	100.0	100.0	100.0

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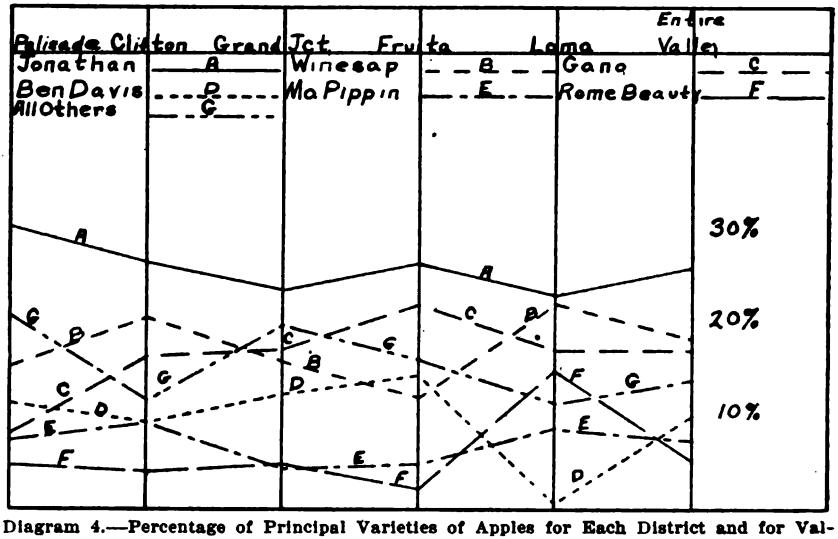

Diagram 4.—Percentage of Principal Varieties of Apples for Each District and for Valley as a Whole (Adapted from Table IV).

CULTURAL METHODS

As a general thing, apple orchards are cover cropped. Alfalfa and clover are mostly used for this purpose. Where properly treated, this is undoubtedly beneficial to the trees, since it adds fertility and humus to the soil and keeps the soil in better condition than when cultivated. Clover is the more desirable of the two, since it is easier to eradicate.

Many growers in 1915 took a fair yield of hay from their orchard cover crops. Ordinarily, this practice is to be condemned, but in most cases since there was no fruit crop, it did not injure the trees noticeably.

PRUNING

In order to produce apples of good size and color, regular pruning is essential. This must be done systematically and intelligently, but fearlessly. The object should be to thin out surplus wood growth, keeping the trees open to light and air, and to induce a low-spreading form of tree rather than a high and narrow one. A considerable amount of thinning may be eliminated by proper pruning.

Few orchardists have paid enough attention to pruning. The failure has been not to prune regularly or properly, and often both are wanting. Many trees are headed and pruned high, so that a very long ladder is necessary for picking. Most of the younger orchards, however, are better pruned.

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Thinning

In ordinary years thinning is absolutely essential to the growing of fruit of marketable size. One must be heartless in order to do good work at thinning, as it is often necessary to remove over half of the apples. It is a paying proposition in the end, as more first-grade fruit is produced than if no thinning had been done.

One can best learn to thin fruit by watching somebody who is expert at this work. By looking at a tree properly thinned and trying to follow this as a model, one soon learns just how much fruit to leave on the tree.

Distance of Planting

The writers were amazed to find apple trees planted so thickly in the Grand Valley orchards. In the majority of cases the trees were set 20 feet or less apart. Common distances of planting were 16x20 feet and 18x20 feet, and several orchards were even set 15x15. One case is recalled of an orchard about 20 years old set 15x15 in which the trees were so interlaced that sunlight seldom touches the ground. There are several such orchards in the Valley.

Permanent apple trees should not be closer than 25 feet each way, and 30 feet is better, depending of course, upon the variety. When set at this distance, fillers may be used, but they should be removed as soon as they interfere with the permanent trees. The latter will occupy very nearly all of the space when they attain their full growth.

One of the best young orchards in the Valley is that of Warren Walker, one-half mile north and one-fourth mile east of Fruitvale Switch. It is a ten-year-old orchard of Jonathan, Gano and Winesap apples set 25x30 feet, and shows what can be obtained with proper setting and good care.

Fillers

A filler is a temporary tree placed between the permanent ones to be removed before it interferes with them. The trees selected for fillers are usually short-lived and come into bearing early. The majority of the orchards in Grand Valley have been planted with fillers, mostly of the pomaceous fruits though stone fruits are sometimes used for this purpose.

The use of fillers is to be recommended where there is ample room between permanent trees, and where the fillers are taken out in time. Too often the fillers are left long enough to spoil the shape of the permanent trees. This practice is the rule rather than the exception and should be condemned.

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Missouri Pippin is the apple most used for fillers, and is admirably adapted to this purpose. It is a small tree, short-lived, and an early and heavy bearer. Grimes Golden, too, is well suited for use as a filler. Pears are also often used and serve the purpose very well. Bartlett and Keiffer are the best for Grand Valley. Peaches and cherries are sometimes planted as fillers, but so little of the apple territory is adapted to their growth that they are almost excluded as fillers among the apples.

SPRAYING

Spraying is absolutely imperative for the production of good apples. The codling moth is so bad in Grand Valley that many growers spray eight to ten times a season, thinking thereby to get clean fruit. As a matter of fact, their fruit is no less wormy than it would have been with four or five sprays applied at the right time. It is the concensus of opinion of the Grand Valley orchardists that with less than four sprays it is impossible to grow clean fruit. However, it has often been proven that fully as much depends upon the time and thoroughness of spraying as upon the number of applications.

The amount of arsenate of lead paste used per 200-gallon tank varies from 5 to 16 lbs., with an average for the Valley of 9 lbs. This is somewhat more than necessary. Eight pounds is enough when kept well agitated in the tank. The powder form of arsenate of lead is used by many in preference to paste. Only half as many pounds of poison is necessary when the powdered form is used.

Pears are sprayed the same as apples except that the calyx spray is omitted, since the calyxes do not close.

The average percent of the clean fruit for the Valley, according to the growers' estimates, is 77½% for apples and 87½% for pears. The estimates vary from 50% to 98%.

The spraying of peaches for twig borer varies from nothing to two applications of spray per year. Few growers, however, can be accused of spraying peaches twice a year. The best practice is to give a dormant spray of lime-sulphur every year just before the buds begin to open. The trees which are regularly sprayed with this solution are more healthy and the fruit is cleaner than when the trees are not sprayed. Some growers prefer arsenate of lead applied shortly after the buds have opened, but general usage favors lime-sulphur.

The spraying should be done according to directions of the State Entomologist, who will gladly furnish instructions for this work.

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Probably less than half of the fruit growers own spraying machines. This means that they must hire a machine to do their spraying. This is usually more expensive and less satisfactory than having a machine of one's own, because the rented sprayers can not always be had at the most effective time for spraying.

The usual charge for a man, team and sprayer is $1.00 for each tank (200 gallons) of arsenical spray applied and $1.25 per tank for lime-sulphur.

PEARS

From a financial standpoint, the pear seems to be the best fruit for Grand Valley to grow. Most pears are grown here to perfection, and the supply is seldom greater than the demand on any good market.

Pears thrive on a heavier soil and succeed where the stone fruits fail. They also stand more neglect than the other tree fruits. Their chief drawback is the danger from pear blight.

Pear Blight

Pear blight, also known as fire blight, spur blight, blossom blight and body blight, is a bacterial disease which has caused the loss of thousands of good pear trees in Grand Valley. The disease was very prevalent in 1915. While it was found all over the Valley, it was worse in a few localities, as for example, just east of Grand Junction, about six miles northwest of Grand Junction, on Orchard Mesa southeast of Grand Junction, and a few localities at Palisade, where the attacks were less severe.

Blight is usually associated with succulent wood growth caused by too much irrigation. It also gives evidence of being related more or less directly to injury by late spring frosts. As blight was found on some orchards which had not been watered and which had made very little wood growth the preceding year, it seemed very plausible that the blight was materially aided by frost. There is no known cure for the disease. The best method of control is to cut out the branches as soon as the blight is discovered. The cut should be made 10 inches or more below the point where the blight occurs. The limb should never be cut off and left as a stub, but should be removed to the nearest lateral branch.

As a precaution against spreading the disease, the tools should be disinfected by dipping into a 1-1000 solution of corrosive sublimate. Nearly all of the blight in Grand Valley in 1915 gave evidence of starting in the blossoms. Some of it did little damage except to the fruit spurs. In many orchards, however, where fruit

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spurs were located on scaffold branches, the disease spread so that the entire limb had to be removed.

Many cures for blight have been advertised and some of them have been tried out by Grand Valley fruit growers. They usually consist of a paint which is applied to the trees, the supposition being that some poisonous substance in the paint will penetrate the bark and be carried in the circulation of the sap and thus kill the bacteria which cause the disease. This belief is erroneous, however, as it is not in the least effective in curing the disease. The authors saw some of these paints tried, and trees which had been painted with it blighted as badly as those to which it had not been applied. The best and surest method of preventing blight is to keep the trees in a slow growing condition by refraining from too frequent irrigation or over-cultivation.

There is a great varietal difference in resistance to blight. Keiffer withstands the disease exceptionally well. Anjou, Garber and Lawrence are fairly resistant while Bartlett and P. Barry are very susceptible to blight.

Pears are grown most extensively in the three eastern districts of the Valley. Clifton takes first place in the production of pears, having 54.3% of the trees in the Valley. Grand Junction is second with 24.3%, and Palisade, third, with 16.2%.

At Palisade nearly half, and at Loma over nine-tenths of the pears have never borne fruit, but two-thirds of the pear trees of the Clifton District, three-fourths of those in the Grand Junction District, and nine-tenths of the pears in the Fruita District are of bearing age.

In the Palisade District, a good many pears are being planted, often replacing peaches. The Loma District has but few pears, and almost all of the trees are young. Practically no pear trees are being planted in the Fruita District, and very few in the Grand Junction District. There are some pear orchards in these two districts whose development it will be interesting to watch. Chief of these are the Wallace orchard about one mile south of Hollandville, the Copeco orchard two miles east of the Hunter schoolhouse, and the Chula Vista orchard one and one-half miles north of the Copeco ranch. These are all large orchards and are planted to good varieties.

VARIETIES

Bartlett is the most popular pear grown in Mesa County. Almost one-half of the trees are of this variety. The Bartlett trees in the Clifton District alone constitute one-fourth of all the pears

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in the Valley. This pear ripens in August. It is of good quality and sells well. The tree bears regularly, but is very susceptible to blight.

TABLE V.—THREE PRINCIPAL VARIETIES OF PEARS, SHOWING PERCENTAGE GROWN IN EACH DISTRICT AND IN ENTIRE VALLEY.

Variety	Palisade	Clifton	Grand Jct.	Fruita	Loma	Entire Valley
Bartlett	56.6	46.5	44.5	25.5	7.8	47.5
Keiffer	26.8	33.8	32.2	28.4	52.2	31.8
Anjou	5.3	8.6	12.7	23.2	9.6	9.8
All others (over 40 varieties)	11.3	11.1	10.6	22.9	30.4	10.9
Totals	100.0	100.0	100.0	100.0	100.0	100.0

Keiffer ranks second in importance. It is a late fall pear, rather poor in quality, and much used for canning. It is an excellent shipper and a good keeper. The tree is very vigorous, an upright grower, and quite resistant to blight. Due to the prevalence of blight in Grand Valley, it is very well adapted for planting.

Anjou comprises nearly 10% of the Grand Valley pear trees. It is a wonderful pear and brings top prices on the market. The fruit ripens late in the fall and keeps well. The quality is excellent. Anjou is fairly resistant to blight, and should be more commonly planted. Its chief faults are, coming into bearing late and not bearing a full crop every year. These failings may be somewhat corrected by judicious pruning.

There are five other varieties, each of which includes 1% or more of the total pears of the Valley. They are: Winter Nelis, 1.8%; Flemish Beauty, 1.7%; Garber, 1.3%; Lawrence, 1.3%; P. Barry, 1%.

About 50 varieties are grown, but those mentioned are the most important. There will probably be many pear trees planted in Grand Valley in the future, and this list should serve as a guide in choosing varieties.

CULTURAL METHODS

Clean cultivation and cover cropping are about equally divided among pears. Cover crops are used more in the western part of the pear belt, while in the eastern part, clean culture is the rule. There is perhaps less tendency to blight when a cover crop is grown. The trees seem to do better when this practice is followed, although they are usually slower growing than when under clean culture. Too frequent irrigations accompanying continued clean cultivation have been the ruin of many good pear orchards.

PRUNING

Pears require considerably less pruning than apples. A common belief is that they should not be pruned any more than is ab-

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solutely necessary. This is wrong, however, as experience has shown that many bad habits may be rectified by proper pruning. Smallness of fruit and irregularity of bearing are among the ills which may be largely corrected in this manner. The pruning of pears has been too much under-estimated and neglected by Mesa County growers.

THINNING

It is essential that in the normal crop year pears should be thinned in order to get proper size. Thinning also tends to promote annual bearing instead of biennial crops as often occur when pears are allowed to mature too heavy crops. If the pear growers would thin heavier, the demand for Colorado pears and the net return from them would increase.

DISTANCE OF PLANTING

Like apple trees, pears are often set much too closely. While they should be allowed 18 or 20 feet, they are often set 15 feet apart, and sometimes as close as 12 feet, in which case the orchards develop into veritable thickets. It is farcical to believe that the profits increase with the number of trees per acre. It will be a glorious day for horticulture when orchardists give their trees plenty of room to develop.

PEACHES

"Palisade Peaches" is a term that has been as popular as "Rocky Ford Melons." There was, indeed, good reason for this, since the Palisade products were superior to nearly all others on the market. The Palisade District is especially adapted to peach growing. Most of the soil is of a sandy loam character, naturally well drained, and easily worked.

The orchards on the north extend clear to the foot of the cliffs, which rise abruptly to a height of several hundred feet above the Valley. These bluffs absorb the heat of the sun and radiate the heat so strongly that peaches grown next to them are from one to several days earlier than those grown lower down. These bluffs are also a great protection against frost. Some growers report that the blush on peaches grown close to the bluffs is often on the side nearest the cliffs, due to the additional heat.

VARIETIES

The Elberta has been the leading variety in Palisade, as in nearly all commercial peach sections. Although there are over 50 varieties grown in Grand Valley, five-sixths of the trees are El-

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bertas. This variety is a freestone, attractive in appearance, a good shipper, and splendid for canning, although rather poor in quality.

Carman ranks second in number of trees, with 3.8% for the Valley as a whole. It is a freestone, creamy white, with a delicious flavor, flesh sometimes streaked with red near the seed, an excellent peach.

Only four other varieties, comprising more than 1% each of the peaches of the Valley, are grown. These are: Salway, 1½%; Crawford, 1.3%; Triumph, 1.1%, and Champion, 1.1%. All other varieties combined constitute 7.3%.

The early peaches are not commercially profitable. They do not stand up well under shipment and the market for them is very limited. Their use must be confined largely to planting for local market.

Cultural Methods

As a general thing, peaches are clean cultivated. Many orchards have been thus handled for so long that practically all the organic matter is burnt out of the soil. The soil in these cases bakes easily and is hard to handle.

Practically all of the peach orchards in which clover or alfalfa was grown and properly handled appeared to be in much better condition than those which had been continually clean cultivated. Some growers, of course, use the cover crop as hay, but where this is done the trees suffer from the treatment. The cover crop is intended to provide organic matter for the land and reduce evaporation of soil moisture. It is ridiculous to suppose that the cover crop can be removed from the land without injury to the trees, for the land cannot support two crops successfully where nothing is returned to it.

Some of the best peach growers in the Valley practice clean cultivation, but supply large amounts of stable manure every year. This supplies the organic matter which is so essential for successful fruit growing. The chief drawback in this practice is the scarcity of manure available. Cover cropping will be best for the majority of orchardists.

Pruning

The peach is a tree that requires very heavy pruning. Unless severely pruned, insufficient new wood is formed to provide for the next year's crop. Whenever neglected, the fruit will be small and unprofitable. Good growers always pay close attention to their pruning.

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THINNING

Thinning is another item that is of extreme importance. The majority of growers do not thin enough, and as a result their fruit is too small to be of first-grade. There is very little danger of thinning too much.

DISTANCE OF PLANTING

There has been a tendency in the past to plant peaches too close together. Numerous orchards have the trees 15x15 feet, and some even less. This is entirely too close. For proper development they should be at least 18, and preferably 20 feet apart.

TABLE VI.—PRINCIPAL VARIETIES OF PEACHES WITH PERCENTAGE GROWN IN EACH DISTRICT AND IN ENTIRE VALLEY.

Variety	Palisade	Clifton	Grand Jct.	Fruita	Entire Valley
Elberta	83.0	88.0	80.5	73.5	83.9
Carman	3.6	4.6	4.4	6.6	3.8
Salway	1.7	0.7	1.5	...	1.5
Crawford	1.3	0.8	0.7	...	1.3
Triumph	1.1	0.7	1.1	...	1.1
Champion	1.0	1.0	2.1	...	1.1
All others (about 50 varieties)	8.3	4.2	9.8	19.9	7.3
Totals	100.0	100.0	100.0	100.0	100.0

PLUMS

Plums are not grown very extensively in Mesa County, totalling only about 6,000 trees, and are grown mostly in the eastern part of the Valley. They are not profitable commercially as a rule, although some varieties yield very fair returns.

Satsuma is the leading variety, numbering almost one-fifth of all the plum trees. It is a good-sized plum with a dark-red skin and firm meat. It is one of the Japanese plums, an upright grower and a fair bearer.

The Italian prune comprises 18.2% of the plums. In size it is medium to large, with dark-blue skin, firm greenish-yellow flesh and good quality. It is a general favorite among the prunes.

The other important varieties, with percentage of each grown, are: Burbank, 9.4%; Agen (French prune), 7.2%; Wild Goose, 6.5%; Hungarian prune, 4.6%; Red June, 4%; Golden Drop (Silver prune), 3.2%; Damson, 3%; Green Gage, 2.5%; Bradshaw, 2.1%; Abundance, 1.8%; Peach, 1.8%.

CULTURE OF PLUMS

Plums are pruned less heavily than peaches, but are thinned much the same. It is almost impossible to prune the native plums satisfactorily, as they are such bushy growers. European and Japanese plums are adapted to almost the same conditions as the peach.

Prunes are also considered under plums in this discussion.

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The native varieties are hardier and succeed under less favorable conditions. Plums should be set 18 to 20 feet apart and given about the same cultural treatment as peaches.

TABLE VII.—PRINCIPAL VARIETIES OF PLUMS AND PRUNES, WITH PERCENTAGE GROWN IN EACH DISTRICT AND IN ENTIRE VALLEY.

Variety	Palisade	Clifton	Grand Jct.	Fruita	Entire Valley
1. Satsuma	29.3	17.2	19.0	2.9	19.5
2. Italian Prune	12.8	26.5	15.0	12.4	18.2
3. Burbank	10.5	9.4	6.7	15.0	9.4
4. Agen (French Prune)	....	3.9	9.4	4.5	7.2
5. Wild Goose	3.0	2.5	8.1	30.5	6.5
6. Hungarian Prune	9.5	4.5	1.7	....	4.6
7. Red June	5.8	2.2	5.8	....	4.0
8. All others (15 varieties)	29.1	33.8	34.3	34.7	30.6
Totals	100.0	100.0	100.0	100.0	100.0

TABLE VIII.—PRINCIPAL VARIETIES OF APRICOTS, WITH PERCENTAGE FOR EACH DISTRICT AND FOR ENTIRE VALLEY.

Variety	Palisade	Clifton	Grand Jct.	Fruita	Entire Valley
Montgamet	38.0	3.6	1.4	...	24.8
Moorpark	18.0	19.0	19.0	41.5	19.8
Newcastle	13.5	0.7	8.7	...	8.7
Royal	7.3	...	...	...	4.7
Miscellaneous and unknown	23.2	76.7	70.9	58.5	42.0
Totals	100.0	100.0	100.0	100.0	100.0

APRICOTS

Only about 3,600 apricot trees are grown in Mesa County, and nearly two-thirds of them are in the Palisade District. They are not very popular with the fruit growers, although it is difficult to understand why they are not grown more extensively.

Apricots thrive under about the same conditions as are required by the peach, although they are somewhat more discriminating. They need about the same care as the peach. Apricots are not very well known by the growers, as to variety, consequently, nearly one-third of the apricots were listed as unknown varieties. Of those known varieties the leading ones were Montgamet, 24.8%; Moorpark, 19.8%; Newcastle, 8.7%; Royal, 4.7%. The miscellaneous and unknown varieties constitute the remaining 42%.

CHERRIES

Grand Valley has about 30 varieties of cherries, comprising approximately 1,300 trees. Palisade leads in the number of trees, followed by Clifton and Grand Junction.

Comparatively few cherries are grown in the western part of the Valley, the conditions here being too severe for their proper development. Many varieties of cherries are grown the names of

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which are unknown to growers, 10% of the trees listed being classed as unknown.

VARIETIES

Royal Duke, 41%, a semi-acid cherry, is the leading variety. It is an upright grower, bearing large, dark-red fruit which has red, tender flesh of excellent quality. It is the favorite cherry and a good seller.

Early Richmond, 18%; Montmorency, 11%; English Morello, 4.9%. These three are sour cherries and are the hardiest varieties grown in the Valley. For canning they are excellent.

Napoleon (Royal Anne), 4.9%, and "Sixteen-to-One," 4.7%, are both sweet cherries and complete the six largely grown varieties.

Other less important varieties are: Mayduke, 2%; Republican, 1.3%; Olivet, 1%, and Bing, 1%.

CULTURE OF CHERRIES

Cherries need 16 to 20 feet distance in the orchard, according to varieties. They demand a fairly dry soil and should be cultivated much the same as the peach and apricot. Little pruning is necessary, although moderate pruning increases the size of the fruit and induces more regular bearing. Sour cherries are tolerably hardy and will endure more rigorous conditions than the sweet varieties. The latter succeed only under favorable conditions.

Cherries have not been very successful commercially in Grand Valley, and will probably be grown only to a limited extent for outside markets.

TABLE IX.—PRINCIPAL VARIETIES OF CHERRIES, WITH PERCENTAGE GROWN IN EACH DISTRICT AND IN ENTIRE VALLEY.

Variety	Palisade	Clifton	Grand Jct.	Fruita	Loma	Entire Valley
Royal Duke	51.2	40.3	37.8	3.7	3.8	41.0
Early Richmond	13.5	22.2	16.6	32.2	...	18.0
Montmorency	4.7	10.5	17.6	7.7	30.4	11.0
English Morello	3.8	2.8	7.8	4.3	16.6	4.9
Napoleon	6.5	5.7	2.7	1.0	...	4.9
16 to 1	2.4	7.6	4.6	1.9	22.6	4.7
All others (20 varieties)	17.9	10.9	12.9	49.2	26.6	15.5
Totals	100.0	100.0	100.0	100.0	100.0	100.0

TABLE X.—NUMBER OF APPLE TREES OF EACH DISTRICT BY AGE CLASS.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Loma	Totals
1- 6 Years	11,000	61,000	29,500	22,500	59,000	183,000
7-10 Years	14,000	196,000	60,000	51,500	26,500	348,000
11-15 Years	11,000	51,000	13,250	18,750	1,500	95,500
16 and above	6,750	46,000	32,000	37,000	1,750	123,500
Totals	42,750	354,000	134,750	129,750	88,750	750,000

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TABLE Xa.—PERCENTAGE OF APPLE TREES OF EACH AGE CLASS PLANTED IN EACH DISTRICT.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Loma	Totals
1- 6 Years	6.0	33.4	16.1	12.3	32.2	100.0
7-10 Years	4.0	56.4	17.2	14.8	7.6	100.0
11-15 Years	11.5	53.5	13.8	19.6	1.6	100.0
16 and above.....	5.5	37.2	25.9	30.0	1.4	100.0

TABLE Xb.—PER CENT OF APPLE TREES OF EACH DISTRICT WITH RESPECT TO AGE.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Loma	Totals
1- 6 Years	25.7	17.0	21.8	17.5	66.4	24.4
7-10 Years	32.8	55.5	44.4	39.6	30.0	46.4
11-15 Years	25.8	14.5	9.8	14.3	1.6	12.7
16 and above.....	15.7	13.0	24.0	28.6	2.0	16.5
Totals	100.0	100.0	100.0	100.0	100.0	100.0

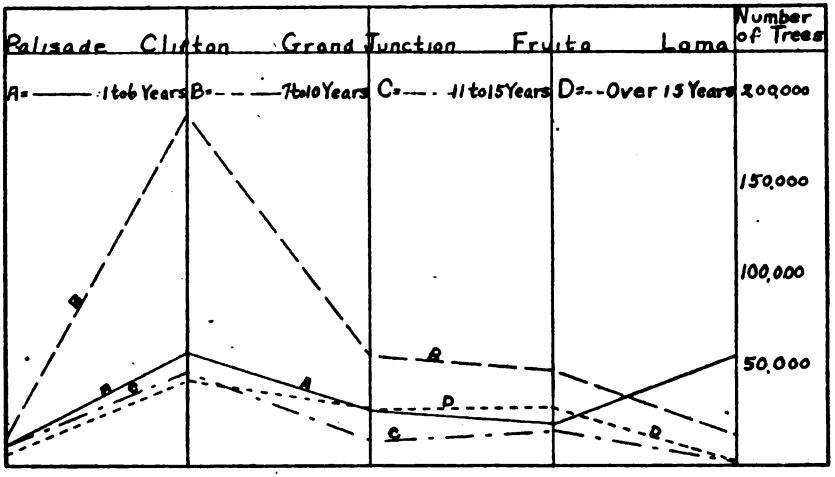

Diagram 10.—Number of Apple Trees in each Age Class for each District (Adapted from Table X).

TABLE XI.—NUMBER OF PEAR TREES OF EACH DISTRICT AND OF ENTIRE VALLEY BY AGE CLASS.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Loma	Entire Valley
1- 6 Years	20,300	47,750	17,400	1,100	365	86,915
7-10 Years	9,900	62,000	30,200	11,000	10	113,110
11-15 Years	7,700	22,500	8,500	600	....	39,300
16 and over.....	6,600	17,250	10,900	900	25	35,675
Totals	44,500	149,500	67,000	13,600	400	275,000

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TABLE XIa.—PERCENTAGE OF PEAR TREES OF EACH AGE CLASS FOR EACH DISTRICT.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Loma	Entire Valley
1- 6 Years	23.2	55.0	20.0	1.4	0.4	100.0
7-10 Years	8.7	54.9	26.8	9.6	...	100.0
11-15 Years	19.6	57.2	21.7	1.5	...	100.0
16 and over	18.5	48.0	30.3	2.5	0.7	100.0

TABLE XIb.—PERCENTAGE OF PEAR TREES OF EACH DISTRICT WITH RESPECT TO AGE CLASS.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Loma	Entire Valley
1- 6 Years	45.6	32.0	26.0	8.0	91.2	31.7
7-10 Years	22.2	41.4	45.2	81.0	2.5	41.0
11-15 Years	17.3	15.0	12.6	4.4	...	14.3
16 and over	14.9	11.6	16.2	6.6	6.3	13.0
Totals	100.0	100.0	100.0	100.0	100.0	100.0

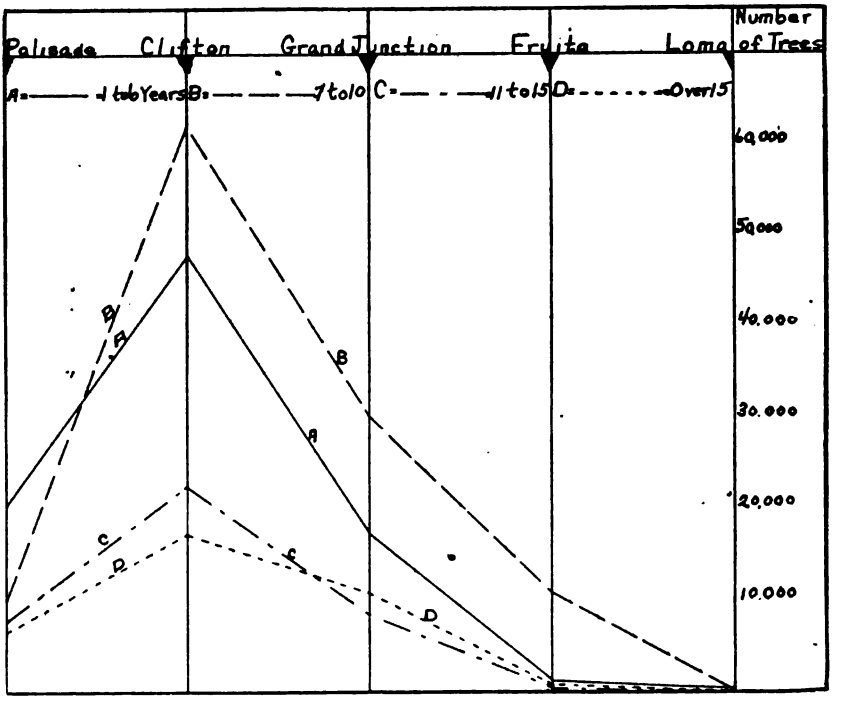

Diagram 11.—Number of Pear Trees in each Age Class for each District (Adapted from Table XI).

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TABLE XII.—NUMBER OF PEACH TREES OF EACH DISTRICT AND OF ENTIRE VALLEY BY AGE CLASS.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Loma	Entire Valley
1- 6 Years	27,000	5,000	2,400	80	20	34,500
7-10 Years	214,000	51,000	5,400	10	65	270,475
11-15 Years	72,000	9,000	1,600	5,250	....	87,850
16 and over	7,000	4,000	1,100	60	15	12,175
Totals	320,000	69.000	10.500	5,400	100	405,000

TABLE XIIa.—PER CENT OF TOTAL PEACH TREES OF EACH AGE CLASS FOR EACH DISTRICT.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Loma	Per-centage Totals
1- 6 Years	78.3	14.5	7.0	0.2	...	100.0
7-10 Years	79.0	19.0	2.0	...	...	100.0
11-15 Years	82.0	10.2	1.8	6.0	...	100.0
16 and over	57.5	32.9	9.1	0.5	...	100.0
Valley Totals	79.1	17.0	2.6	1.3	...	100.0

TABLE XIIb.—PER CENT OF TOTAL PEACH TREES OF EACH DISTRICT WITH RESPECT TO AGE.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Loma	Entire Valley
1- 6 Years	8.4	7.2	22.8	1.5	20.0	8.5
7-10 Years	67.0	74.0	51.5	0.2	65.0	66.8
11-15 Years	22.4	13.0	15.2	97.2	...	21.7
16 and over	2.2	5.8	10.5	1.1	15.0	3.0
Percentage total	100.0	100.0	100.0	100.0	100.0	100.0

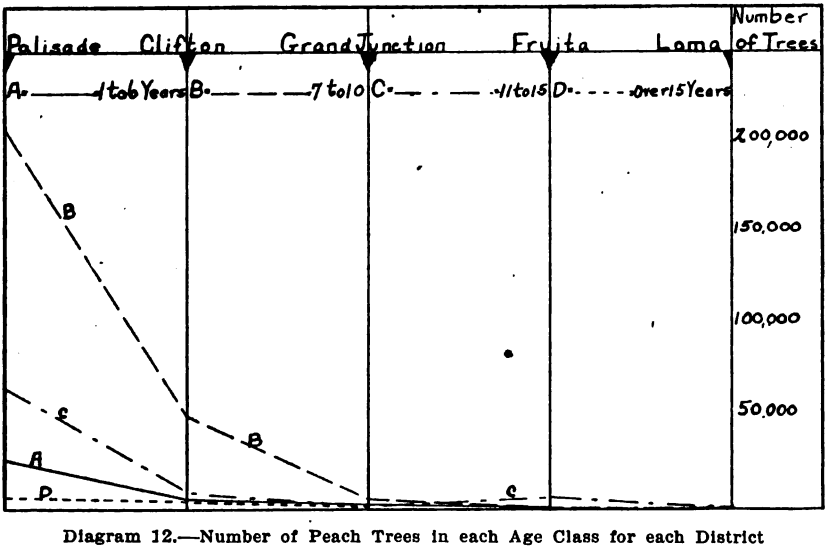

Diagram 12.—Number of Peach Trees in each Age Class for each District (Adapted from Table XII).

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TABLE XIII.—PERCENTAGE OF PLUM TREES OF EACH DISTRICT FOR EACH AGE CLASS.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Entire Valley	Total Trees for Valley
1- 6 Years	8.5	2.6	9.6	8.5	6.4	385
7-10 Years	54.0	50.6	35.3	11.2	43.6	2,615
11-15 Years	30.5	38.4	10.6	22.7	27.7	1,660
Over 15 Years	7.0	8.4	44.5	57.6	22.3	1,340
Percentage totals	100.0	100.0	100.0	100.0	100.0	
Total Plum Trees	1,750	2,150	1,600	500	....	6,000

TABLE XIV.—PERCENTAGE OF APRICOTS OF EACH DISTRICT FOR EACH AGE CLASS.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Entire Valley	Total Trees for Valley
1- 6 Years	13.0	17.0	16.4	3.6	13.6	490
7-10 Years	45.0	45.0	42.8	18.6	43.0	1,550
11-15 Years	31.5	36.0	10.8	17.6	30.0	1,080
Over 15 Years	10.5	2.0	30.0	60.2	13.4	480
Percentage totals	100.0	100.0	100.0	100.0	100.0	
Total Apricot Trees	2,200	800	350	250	....	3,600

TABLE XV.—PERCENTAGE OF CHERRY TREES OF EACH DISTRICT FOR EACH AGE CLASS. TOTAL NUMBER OF TREES FOR ENTIRE VALLEY.

Age Class	Palisade	Clifton	Grand Jct.	Fruita	Loma	Entire Valley	Total Cherries for Valley
1- 6 Years	12.8	7.3	19.0	51.3	97.0	18.2	2,360
7-10 Years	55.4	53.3	49.0	15.0	....	48.0	6.250
11-15 Years	17.0	35.8	19.0	7.0	....	21.0	2,730
Over 15 Years	14.8	3.6	13.0	27.7	3.0	12.8	1,660
Percentage Totals	100.0	100.0	100.0	100.0	100.0	100.0	
Total Cherries for Val.	5,300	3,175	3,150	1,075	300	....	13,000

VARIETIES OF FRUIT GROWN IN THE GRAND VALLEY

APPLES

Aiken Red
Alexander
[2]Arkansas (Mammoth Black Twig)
[2]Arkansas Black
Babbitt
Bailey Sweet
[3]Baldwin
Barbour's Pride
Basket
Beitigheimer
[3]Belleflower (Yellow)
Ben Davis
Ben Hur
Benoni
Bismarck
[1]Black Ben
Blue Pearmain
Buckingham
Canada Red
Champion
[3]Chenango Strawberry

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Cole Quince
Colorado Orange
Cooper Market
[1]Delicious
Dominie
Duling
[3]Early Harvest
Early Pennock
English Russett
Fallowater
Fall Orange
Fall Pippin
Fall Wine
[2]Fameuse
Flora Bell
French Pippin
Fulton
[1]Gano
[2]Geniton
Gideon
Golden Russett
[3]Gravenstein
[2]Grimes Golden
Haas
Hawley
Hubbardston
Huntsman
[3]Hyslop (Crab)
Ingram
Iowa Blush
Isham's Sweet
[3]Jefferis
[1]Jonathan
Keswick
Kinnard
[2]King David
King (Tompkins County)
[2]Lawver
Limbertwig
[3]Livland Raspberry
Lowell
Loy
[3]Maiden Blush
Mann
Martha
[2]McIntosh
[3]McMahon (White)
Milam
Minkler
[2]Missouri (Pippin)
Mrs. Bryan
Munson (Sweet)
Newtown Pippin
[2]N. W. Greening
[2]Northern Spy
Nova Scotian
[2]Oldenburg (Duchess)
Opalescent
Ortley (White Belleflower)
[2]Paragon
Payne
Peck
[3]Peewaukee
Plumb Cider
Rambo
Ramsdell
[3]Red Astrachan
Red June
Red Pearmain
Red Stripe
R. I. Greening
Romanite
Roman Stem
[1]Rome Beauty
Roxbury Russet
Salome
Santa Clara King
[2]Senator
Shackleford
Shockley
Siberian (Crab)
Smith Cider
Smokehouse
[3]Spitzenburg
Stark
[1]Stayman
Steele's Red
Summer Pearmain
Summer Pippin
Summer Queen
Sweet Bough
Thunderbolt
[3]Tolman (Sweet)
[3]Transcendent (Crab)
Trenton Beauty
Twenty Ounce Pippin

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[3]Utter Red
Vandevere Pippin
[3]Wagener
Walbridge
[2]Wealthy
Westfield
[3]White Winter Pearmain
White Winter Pippin
[3]Whitney No. 20 (Crab)
Williams
Willow Twig
Wine (Hay's Winter Wine)
[1]Winesap
[2]Winter Banana
Winter Paradise
Wolf River
[3]Yellow Transparent
[2]York Imperial

1—Recommended for commercial planting.
2—Varieties for semi-commercial, or, in certain localities, commercial planting.
3—Best adapted for home use and in some instances for semi-commercial use.

APRICOTS

Breda
Cole's Mammoth
Colorado
Early Golden
Hemskirke
[1]Jackson
Japan
Jones
[1]Montgamet
[1]Moorpark
[1]Newcastle
Peach
[1]Royal
Russian
Smith's Early
Tilton

CHERRIES

Baldwin
Bing's
Choisy
Dyehouse
[1]Early Richmond
[1]English Morello
Knight, s.
Lambert, s.
Late Duke
[1]Lewelling, s. (Black Republican)
[1]May Duke
[1]Montmorency
[1]Napoleon, s.
Occident (Sultan)
Olivet
Oxheart, s.
Reine Hortense
[1]Royal Duke, s. a.
Rocky Mountain (P. Bessayi)
[1]Sixteen-to-One, s.
Tartarian, s.
[1]Windsor, s.
Wood (Gov. Wood), s.
Yellow Spanish, s.

CURRANTS

Albert (Prince Albert)
[1]Cherry
[1]Fay (Fay's Prolific)
Holland
London
[1]North Star
[1]Perfection
Pomona
[1]Red Cross
[1]Red Dutch
Versaillaise
[1]White Grape (Imperial White)
Wilder

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Gooseberries

Berkeley (Dwinelle)
Chataqua
Champion (Mills Champion)
Crown Bob
[1]Downing
Industry
[1]Houghton
Josselyn (Red Jacket)
[1]Oregon (Oregon Champion)
[1]Pearl
Smith (Smith's Improved)
Wellington (Wellington's Glory)
Whitesmith (Sir Sidney Smith)

1—Best for commercial planting.
s.—Sweet.
s. a.—Semi-acid.

Grapes

Agawam
America
Alexandria
[2]Black Hamburg
Brighton
[1]Concord
[2]Cornichon
[1]Delaware
Duchess
[2]Flame Tokay
Goethe
Isabella
Ives
Lindley
[2]Mission
[1]Moore (Moore's Early)
[1]Niagara
Prentiss
Salem
[2]Suldanina (Thompson's Seedless)
Wilder
[1]Worden

Peaches

Alexander
Alton
Banner
Barnard
[1]Belle of Georgia
Bergen
Bokhara
[1]Carman
Chairs Choice
[1]Champion
Chinese Cling
[1]Crawford (Early)
Crawford (Late)
Crosby
Decker
Dewey
Early Rivers
Early York
[1]Elberta
Emma
Favorite
Foster
Francis
Globe
Gold Drop
Greensboro
[1]Hale's Early
Indian Cling
J. H. Hale
Krummel-
Lemon Cling
Lovell
Mamie Ross
Mathew's Beauty
Mayflower
Mellow St. John
Moore's Favorite
[1]Mountain Rose
Muir
New Prolific
Niagara
Oldmixon Cling

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Oldmixon Free
[1]Orange Cling
[1]Phillips Cling
Prince
Reeve's Favorite
Richmond
Russell
Smock
Sneed
Steven's Rareripe
Stump-the-World
Victor
Wheatland
Wonderful

1—Best for commercial planting.
2—Recommended only for home planting.

PEARS

[1]Anjou
Anjou Dwarf
Angouleme (Duchess)
Angouleme (Duchess) Dwarf
Braseck
[1]Bartlett
Bartlett Dwarf
Bosce
Boussock
Brandwine
Clairgeau
[1]Clapp's Favorite
Columbia
Cornice
Easter
[1]Flemish Beauty
Fred Clapp
Garber
Howell
Idaho
[1]Kieffer
King Carl
Koonce
Krull
[1]Lawrence
Lawson
LeConte
Lincoln
Louise Bonne
Lucrative
Margaret
Mt. Vernon
Orange
[1]P. Barry
Reihl's Best
Roosevelt
Rossney
Rutter
[1]Seckel
[1]Sheldon
Sugar
Summer Doyenne
Urboniste
Vicar
White Doyenne
Wilder
Winter Bartlett
[1]Winter Nelis

PLUMS

[1]Abundance
Agen
American Eagle
Archduke
Bavay
Bradshaw
Brittlewood
[1]Burbank
Burwood
Chabot
Cheney
Climax
Clyman
[1]Damson
[1]DeSoto
Duane
[1]Fellenberg (Itanial Prune)
Forest Garden
[1]German (Prune)
Giant (Prune)
Golden
Golden Beauty

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[1]Green Gage
Hawkeye
Hudson
Hungarian Prune
Imperial Gage
[1]Lombard
Marianna
Miner
[1]Moore's Arctic
[1]Peach
Pond
Quackenboss
[1]Red June
Rockford
Rollingstone
[1]Satsuma
Shropshire
Simon's
Sugar
[1]Surprise
[1]Terry
Tragedy (Prune)
[1]Weaver
Wickson
Wild Goose
[1]Wolf
[1]Wyant
Yellow Egg

1—Best for commercial planting.

Brambles
(Blackberries, Dewberries and Raspberries)

Blackberries

Acme
[1]Briton (Ancient Briton)
Early Harvest
Eldorado
Erie
Kittatiny
Lawton
Mercereau
[1]Minnewaska
[1]Snyder
Stone
Wilson

Dewberries

Bartel
[1]Lucretia
Mayes (Austin)

Raspberries

Brandwine (Wilmington)
[1]Columbian, p.
[1]Conrath, b.
Cumberland, b.
[1]Cuthbert
Golden (Golden Queen)
[1]Gregg, b.
[1]Kansas, b.
[1]King
Loudon
[1]Marlboro
McCormick (Mammoth Cluster), b.
Nemaha, b.
Ohio, b.
Palmer, b.
St. Regis
[1]Shaffer, p.
Soubegan
[1]Turner
Tyler

Strawberries

Aroma
[1]Bederwood
Brandywine
[1]Bubach
Captain Jack
Crawford
Cumberland
Downing

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[1]Dunlap (Senator Dunlap)
Gandy
[1]Glen Mary
[1]Haverland
Ivanhoe
Jessie
[1]Marshall
Parker Earle
[2]Progressive (Everbearing)
Saunders
Sharpless
Splendid
Thompson
[1]Warfield
[1]Wm. Belt
Wilson
Wolverton

1—Best for commercial planting.
2—Recommended for home use.
b.—Black caps.
p.—Purple Cane.

THE FUTURE OUTLOOK FOR FRUIT GROWERS IN GRAND VALLEY

The readers of this bulletin will naturally wonder whether fruit growing in the Grand Valley has any future before it or not, whether the decline in productiveness, in prices obtained for fruit, and in the deterioration of some of the orchards will not permanently cripple the fruit industry in Grand Valley. It is undoubtedly true that fruit growing in the Grand Valley will be restricted to certain limited areas where fruit growing under all conditions will be reasonably safe. It is also true that a considerable portion of the land now in orchards will be put into agricultural crops because of the unfavorable conditions of these lands for fruit.

The Palisade and Clifton Districts, and part of the Grand Junction District, will very likely remain profitable fruit growing sections. For the Fruita and Loma Districts as a whole, the writers are less hopeful. Many of the orchards in the Fruita District are unprofitable at present, and more are reaching this state each year. A large part of the young orchard at Loma will probably never pay for itself. True, some of it will, with proper care, develop into profitable orchards, but as a district the odds are against this.

For profit, pears give the most promise. There is usually a good market for them, and they may be grown very well east of Grand Junction. Apples will always remain profitable, and, for a long-time average, may give as much return as pears.

The by-product problem must be solved before peach growing will be permanently profitable.

SUMMARY

The fruit industry in Grand Valley, Mesa County, as a commercial enterprise is about 20 years old. Fabulous prices were ob-

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tained for fruit eight or ten years ago. Wildcat speculation was prevalent for a time. The business is now in the process of re-adjustment from the speculative basis. Many orchards and many growers belonging to the speculative class are being eliminated in the re-adjustment. Land is getting back to sensible prices and a few years will no doubt see the business flourishing again.

There are nearly 16,000 acres of orchard in the Valley. Of this, over 10,000 are apples, 3,000 peaches, 2,400 pears, and less than 200 acres plums, apricots and cherries.

Probably more than 2,500 acres of orchard have been pulled out in the last five years, most of this being removed from the western portion of the Valley.

Most of the best orchards lie east of Grand Junction. The older ones are mostly in the Fruita District and many are being pulled out to make the land available for general farming.

Less than one-third of the fruit trees of Grand Valley are over twelve years old.

The orchards are, as a rule, too small. The average size for the Valley is slightly below nine acres.

Too many farmers grow fruit exclusively, and a year of poor prices or crop failure is disastrous to them.

More land must be devoted to general farming, stock raising and dairying and the average fruit grower must grow something besides fruit in order to be most successful.

Marketing is the worst problem the growers have to solve.

The pack of fruit must be standardized and poor fruit utilized in by-products.

Clean cultivation has been practiced too much, but is now giving way to the more sensible system of cover cropping.

Due to over irrigation, the water table has risen in some places to within 5 feet, or less, of the surface. Many orchards have been ruined by seepage and a drainage system is probably to be installed throughout the entire Valley to give relief from this trouble.

The codling moth is very bad. Most growers spray four to six times with arsenate of lead, using 4 or 5 pounds of paste to 100 gallons of water. The average cost of spraying apples per acre per season is $20.00.

Peaches are generally sprayed for twig borer with lime-sulphur just before the buds begin to open. Some orchardists spray with arsenate of lead shortly after the leaves come out.

The ravages of pear blight have some years been great. Many acres of good pear orchard have been ruined by this disease. The industry, however, continues to yield good profits.

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The average cost of production per box of fruit, laid down at the platform, including all expenses, as determined from the estimates given, is, for apples 61.2c, pears 60.5c, peaches 31.2c.

The average number of cars of fruit shipped out of the Grand Valley for the years 1911 to 1915, inclusive, is about 2,525 per year.

The average yield per acre for the years 1911 to 1915 has been about 25% of a car for apples, 30% of a car for pears, and 55% of a car for peaches per year for all bearing orchard in the Valley.

About 30% of all the irrigated land on the north side of the river is planted to fruit trees, while only about 5% of the irrigable land south of the river is set to orchard. Over 80% of the orchard in the Valley is located north of the river, less than 20% being on the south side.

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NATIVE VEGETATION AND CLIMATE OF COLORADO IN THEIR RELATION TO AGRICULTURE

By WILFRED W. ROBBINS

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NATIVE VEGETATION AND CLIMATE OF COLORADO IN THEIR RELATION TO AGRICULTURE

By WILFRED W. ROBBINS

*INTRODUCTION**

A close relationship exists between climate and vegetation, whether vegetation in the native state or under cultivation. Each climatic region has its characteristic natural plant life. There are, also, certain crop plants best suited to every distinct climatic area.

Colorado has a variety of climates. One may travel from the warm valleys of the Western Slope, or from the Great Plains, to the crest of the Continental Divide, and pass through as many distinct climates as he would in travelling from Virginia to arctic Greenland. This variety is largely a result of differences in altitude, although range of latitude and topographic diversity are also responsible. The lowest point in Colorado has an elevation of 3,386 feet, and the highest, 14,402 feet, thus giving an altitudinal range of 11,016 feet. The latitudinal range is 4° (37° to 41°). Chiefly as a consequence of the great altitudinal variation, Colorado has many distinct climates, each with native plants and with crop possibilities peculiar to it.

Climatic and Local Environmental Factors.—It is worthy of mention that native plants and crop plants are subject to the same environmental factors. We may separate the external factors affecting plants into two classes: *Climatic factors and local (edaphic) factors.* Climatic factors, such as light, temperature of

*This bulletin is an outgrowth of a number of years of observation and study of the native vegetation of Colorado in its relation to climate and to agriculture. During the summer season of 1916, special attention was directed to this study, and an automobile trip, which covered the territory shown in Fig. 1, was taken for the purpose of testing conclusions arrived at, and finding new relations. Little consideration is given to the question of the value of native plant life as an indicator of the local physical conditions of the environment. Such detailed study, however, is of much practical importance, and it is planned to engage in such a study later. But, the attempt here is to point out the broader relations between our large native plant associations and the principal climatic factors under which they are growing, and to show their relation, in a very general way, to Colorado agriculture. The writer realizes that a number of conclusions herein drawn rest upon insufficient data, and therefore are subject to more or less modification, as further information comes to hand. Furthermore, he well knows that climatological data employed, in the form given us, in the interpretation of biological phenomena, although not without qualitative meaning, frequently have little quantitative value.

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the air, moisture of the air, precipitation (rainfall and snowfall), wind, and atmospheric pressure, are those which work over areas of great extent. Local factors, such as temperature of the soil, water and air in the soil, texture and composition of the soil, life of the soil, direction of slope, degree of slope, etc., are those which work within rather narrow limits and are determined by local physical conditions. Differences in the character of the vegetation of a certain climatic area are determined by the local factors just mentioned. For example, the climatic type of vegetation over the Great Plains is that of a dry grass-land (grass-steppe). Within this large climatic grass-land area, there are local variations in the plant covering which may be due to differences in soil texture, slope, exposure, etc. For example, in soil readily penetrated by water, *Psoralea,* a deep-rooted plant, is locally very abundant; again, in low, seeped places, alkali plants may prevail, and on shale knolls, *Yucca* be locally dominant.

There are many possible combinations of factors that may operate upon a plant. In a state like Colorado, with its varied climatic conditions, its slopes and exposures of all degrees, its highly varied geologic structures calling forth many soil types, these combinations become innumerable. Each combination of environmental factors calls forth corresponding activities in the plant life; and these activities are represented, in a practical way, by the quality and quantity of the crop yield.

Man's Control of the Environmental Factors.—Man, in his agricultural pursuits, has attempted, and often successfully, to artificially modify the external conditions about the plants he is growing. He may decrease the light intensity by shading or thick planting, increase the light intensity by thinning the plants, lengthen the duration of light by the use of artificial light, as is sometimes done in the forcing of vegetables in the greenhouse, and may even change the quality of the light by the use of stained glass, although such a practice is not practical. He may increase the temperature of the air about plants by the use of hot-houses, hot-beds, and by different methods of orchard heating, and decrease the temperature of the air by cold-houses, and by shading. Moisture in the air is increased by housing, by shading, by planting so as to have a thick stand, and by having windbreaks; and the moisture may be decreased by housing and by having a thin stand. Man may modify the effects of wind movements by windbreaks and by increasing the density of crop stand. Local factors are also more or less under control by man. The structure of the soil may be modified by cultivation and by the application of

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water and fertilizers. The amount and quality of air in the soil may be changed by cultivation and by the use of water and fertilizers. The quantity of water in the soil and soil temperature may be controlled by irrigation, drainage, fallowing, windbreaks, and by the kind of crop planted. The nutrient material in the soil may be changed by the use of fertilizers, by irrigation, drainage, the kind of crop planted and the cropping system. And even the life of the soil, composed as it is of innumerable microscopic plants and animals, may be regulated by irrigation, drainage, method of cultivation, cropping system, and by the use of fertilizers.

Of the two groups of environmental factors, *climatic* and *local*, the former group is less under the control of man than the latter, except when he is dealing with a very small group of plants. However, it is possible for man to modify and control, even in an extended way, the structure of the soil, the "plant food" of the soil, and the plant and animal life of the soil. It is quite beyond his powers to modify and control, in general farming practice, light, air temperature, moisture of the air, precipitation and movements of the air, except in a limited way by means of windbreaks in the last.

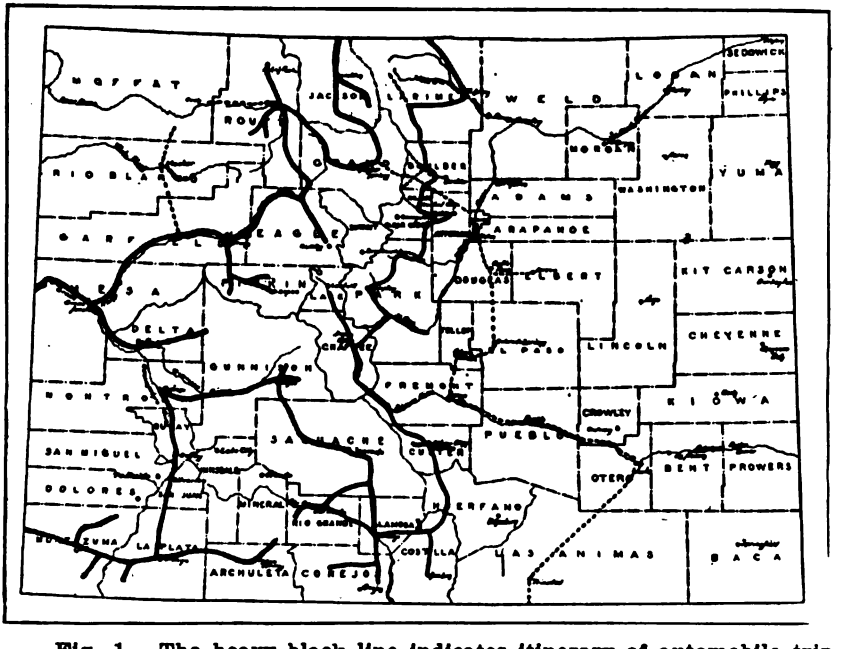

Fig. 1.—The heavy black line indicates itinerary of automobile trip during summer of 1916. Dotted line indicates wagon and train trips.

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*CLIMATIC FACTORS**

TEMPERATURE OF AIR

Mean Annual Temperature.—The Arkansas Valley up as far as Canon City, the plains east of the Arkansas-Platte Divide, a strip along the eastern foothills from below Denver to Boulder, and the lower Grand and Uncompaghre sections, have a mean annual temperature of 50°† and above. An average yearly temperature of between 45° and 50° is experienced by the northern Great Plains, the Arkansas-Platte Divide and a belt along the eastern foothills up to about 7,000 or 7,500 feet. Much of the sagebrush country below 7,500 feet in the southwestern counties and in western Dolores and San Miguel counties, and also narrow belts running up the Grand, Gunnison and Uncompaghre rivers, have a mean annual temperature of between 45° and 50°. The foothills proper along the eastern mountain front, the entire level of San Luis Valley, thousands of square miles in Moffat, Routt and Rio Blanco counties, and extensive areas in the southwest and middle-west valleys below about 9,000 feet, have a mean annual temperature of 40° to 50°. Yearly average temperatures of 35° to 40° prevail in North Park, Middle Park, and South Park. Most stations above 10,000 feet have a mean annual temperature below 35°.

Mean Summer‡ Temperature.—Fig. 2 shows the mean summer temperatures for Colorado. The summer temperature is of more significance in its relation to agriculture than that for the year. The 70° isotherm follows very closely the 5,000-foot contour line. The effect of the Arkansas-Platte Divide is shown in the eastward deflection of the isotherms for 70° and 65°. The 65° summer isotherm and the 45° annual isotherm touch similar points quite generally. That portion of the State with a mean summer temperature between 60° and 65° ranges in altitude from about 6,500 feet to 8,500 feet, and within this belt a type of agriculture which is sometimes called "high-altitude agriculture", is practiced. The summer mean for the San Luis Valley is near 60°; the same temperature prevails throughout Middle Park. North Park has a summer mean between 55° and 60°. It is well to keep in

*Throughout the bulletin, the climatological data are from the records of the Colorado Section of the United States Department of Agriculture, Weather Bureau, and from Bulletin 182, by Robert E. Trimble, of the Colorado Agricultural Experiment Station.

†All temperatures throughout are Fahrenheit, unless otherwise indicated.

‡The "summer" months here considered are June, July and August.

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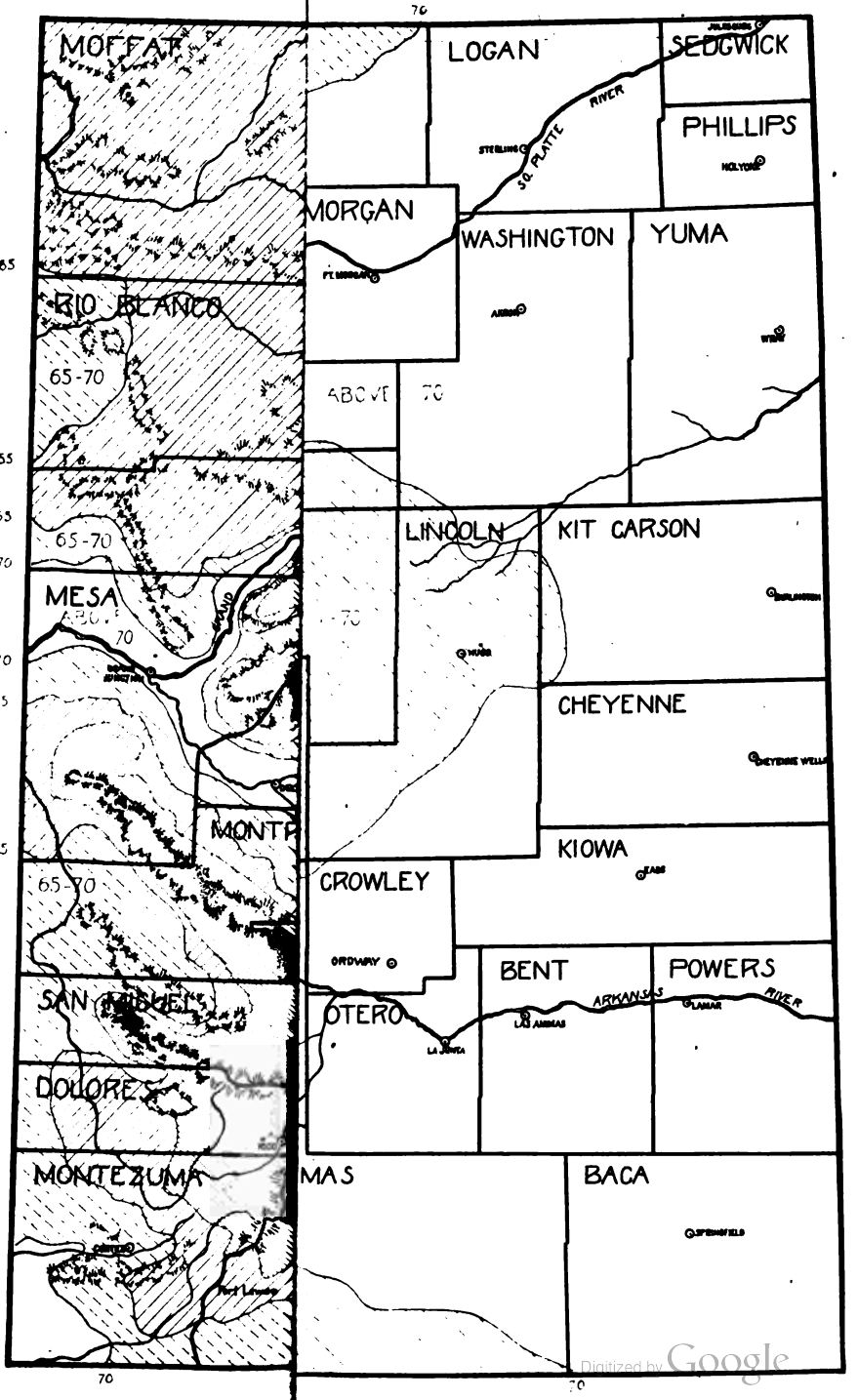

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mind the fact that two localities with the same mean temperature for any period may experience quite marked differences in their temperature extremes for the same period.

Mean Annual March of Temperature.—The march of temperature from month to month throughout the year may be shown graphically in a curve (Fig. 3). A steep curve signifies a wide temperature range, while a flat curve indicates a narrow range. The mean temperature for any month is seen at a glance, as are also the warmest and coldest months.

Decrease of Temperature with Altitude.—The rate of decrease of temperature varies with altitude and season. The rate seems

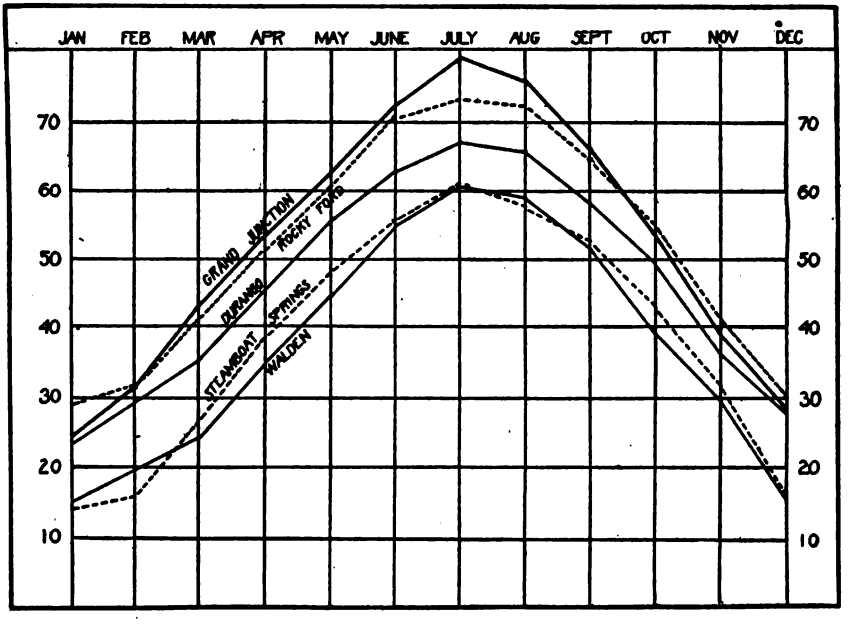

Fig. 3.—Mean annual march of temperature for Rocky Ford, Grand Junction, Durango, Walden, and Steamboat Springs.

to be less at high altitudes than at low, and less in winter than in summer. The following table shows the decrease in temperature per 1,000 feet elevation, for a number of stations in Colorado, for the year 1915. The stations compared are within the same drainage system.

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TABLE I.—DECREASE IN TEMPERATURE WITH INCREASE IN ALTITUDE.

Station	Altitude in Feet.	Decrease of temperature per 1000 feet elevation (1915) Monthly and yearly means												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Salida	7035													
Leadville	10248	2.5	3.3	3.9	3.2	3.5	3.4	3.1	2.3	2.3	2.9	4.3	3.3	3.2
Denver	5272													
Idaho Springs..	7543	1.4	2.2	1.4	3.0	3.3	2.9	2.9	3.3	3.2	2.9	3.2	2.2	2.7
Ft. Collins.....	4985													
Long's Pk. ... (near)	8600	1.4	1.9	2.2	3.2	3.1	3.3	3.0	3.0	2.6	1.9	2.1	1.1	2.6
Colo. Springs...	6098													
Lake Moraine..	10265	1.8	2.5	3.2	3.4	3.3	2.3	2.7	2.8	2.9	2.5	2.8	2.4	2.6
Glenwood Spgs.	5758													
Aspen	7981	—.03	3.2	5.3	5.0	4.1	3.2	2.5	3.1	3.2	2.7	3.1	3.1	3.2
Durango	6546													
Silverton	9400	2.3	3.4	4.1	2.9	4.2	5.2	2.2	4.2	3.5	3.1	2.9	0.9	3.5
Glenwood Spgs.	5758													
Marble	7951	—.03	2.0	3.4	2.7	2.3	2.1	1.7	1.8	2.1	2.0	1.7	1.0	0.8
Garnett	7576													
Wagon Wh Gap	9610	1.6	3.3	5.2	4.0	4.3	3.9	2.6	3.2	3.4	2.7	2.3	1.6	3.3
Delta	5025													
Cedaredge	6175	—3.4	0.04	2.3	3.3	3.2	4.6	4.5	..	2.0	—.01	2.1	0.04	..
Boulder	5347													
Frances	9300	2.5	2.6	2.0	3.1	3.5	3.3	2.9	2.7	2.7	2.6	3.4	2.0	2.3
Average.....		.98	2.5	3.4	3.4	3.5	3.5	2.3	2.9	2.3	2.3	2.3	1.3	2.7

The difference between low and high altitude stations in the mean temperatures for January is less than for any other month. In fact, the records show that the mean temperature for January, 1915, at Marble (7,951 feet) is .6° higher than that at Glenwood Springs (5,758 feet), and that at Cedaredge (6,175 feet) the mean temperature for January of that year was 3.9° higher than at Delta (5,025 feet). In general, the differences in temperature between low and high altitude stations are less during the winter months than during the summer months, as may be seen from Table I. As a general rule, it may be stated that in Colorado an increase in elevation of 1,000 feet decreases the mean temperature for the year about 2½°; for the summer months (June, July, August), about 3°; for the fall, about 2½°; winter, about 1½°; and spring, about 3½°. That is, in order to effect a decrease of 1° in the mean temperature for the year, one must ascend about 370 feet; to effect a decrease in the mean temperature for the spring, about 294 feet; summer, about 322 feet; fall, about 361 feet; and for the winter, about 588 feet. There is a retardation in the development of the vegetation, amounting to about 13 days for every 1,000 feet increase in altitude.

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Daily Range of Temperature.—By daily range of temperature is meant the difference between the highest and lowest temperature which occurs during the day. The daily ranges of temperatures are quite high in Colorado, particularly on the plains and in the high and broad mountain parks. One may gain an idea of the *greatest* daily ranges of temperature at a number of stations in Colorado, by examining data for 1915 in the following table:

TABLE II.—GREATEST DAILY RANGES OF TEMPERATURE (1915).

Station	County	Altitude	Jn.	Fb.	Mr.	Ap.	My.	Ju.	Jly.	Ag.	Sp.	Oc.	Nv.	Dc.
Blue Val. Ranch.	Grand	7150	..	49	44	41	44	42	..	49	49	48	..	..
Canon City.....	Fremont ..	5343	48	48	48	46	41	43	44	..	42	57	51	48
Chey. Wells.....	Cheyenne..	4279	48	45	44	41	42	43	36	38	37	56	46	37
Cortes ..,.....	Montezuma.	6100	46	40	..	..	43	46	61	52	..	..	..	..
Denver	Denver ...	5198	38	39	38	34	37	37	38	36	32	37	36	41
Durango	La Plata..	6534	40	46	38	43	44	46	45	43	42	51	41	37
Frances	Boulder ..	9300	33	32	36	..	33	31	35	30	30	35	24	42
Garnett	Saguache..	7576	51	57	47	46	51	49	47	46	46	53	53	54
Gd. Junction ...	Mesa	4602	31	31	36	33	34	36	35	36	33	38	33	27
Greeley	Weld	4600	51	56	45	45	51	44	..	51	51	59	49	51
Gunnison	Gunnison..	7670	58	53	48	48	52	53	49	50	50	54	52	39
Hayden	Routt	7500	39	54	68	44	57	66	55	50	50	52	46	42
Lamar	Prowers ..	3592	54	53	49	45	48	38	41	46	45	59	53	50
Long's Pk. (nr.).	Larimer ..	8600	48	41	42	32	44	40	40	45	40	44	37	46
Meeker	Rio Blanco	6182	50	55	..	46	49	48	48	46	59	56	50	44
Pagosa Spgs....	Archuleta..	7108	64	67	52	46	47	..	56	44	47	..	69	53
Spicer	Jackson ..	8700	34	36	36	35	38	52	41	..	..	36	60	54
Steamboat Spgs..	Routt	6500	50	58	51	45	46	53	54	55	55	57	52	47
Trinidad	Las Animas	5994	48	45	38	38	38	40	42	37	..	45	44	45
Westcliffe	Custer ...	7861	54	53	47	45	44	48	50	45	52	56	55	68

The maximum daily ranges throughout Colorado are high; but the figures given in the above table do not consider sun temperatures, and hence do not represent the extremes of temperature to which sun plants are exposed. There is a marked difference between sun and shade temperatures at high altitudes, and this difference becomes greater as the elevation increases. Temperature differences in the sunshine and shade may be judged from the following data taken from Hann's Handbook of Climatology:

TABLE III.—SUN AND SHADE TEMPERATURES AT DIFFERENT ALTITUDES.

Altitude of Station (feet)	Temperatures		
	Sun	Shade	Difference
150.9	106.70	86.00	20.70
8431.7	113.90	76.10	37.80
9481.6	118.58	68.18	50.40
65.6	100.04	89.96	10.08
5905.5	111.20	79.70	31.50
7644.3	115.52	66.35	49.14
9776.9	171.10	42.80	128.30

The heating effect of the sun at high altitudes is much greater than at low elevations. This means that at high altitudes, objects heat up much more quickly during the day than at low altitudes.

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It has been estimated that the sun's rays, in passing from the upper boundary of the air to sea level, lose 20% of their heating effect. Shortness of growing season is compensated for, in a large measure, by the intensity of the sun's rays.

Absolute Annual Range of Temperature.—The absolute annual range of temperature is the difference between the highest and lowest temperatures of the year. This range gives us an index of the severity of the climate, although not always a reliable one. Very low temperatures with a snow cover on the ground are less harmful to vegetation in the dormant state, than when there is no snow cover. The following table gives the absolute annual range of temperature for a few Colorado localities. The temperatures are for the shade, as are all ordinary meteorological records.

TABLE IV.—ABSOLUTE ANNUAL RANGE OF TEMPERATURE (1915).

Station	County	Altitude (in feet)	Absolute Annual Range of Temperature
Arriba	Lincoln	5243	100
Aspen	Pitkin	7909	106
Beuna Vista	Chaffee	7955	95
Boulder	Boulder	5346	98
Castle Rock	Douglas	6220	116
Cheyenne Wells	Cheyenne	4279	107
Colorado Springs	El Paso	6098	98
Delta	Delta	4965	115
Denver	Denver	5272	98
Durango	La Plata	6534	99
Ft. Collins	Larimer	4985	106
Frances	Boulder	9300	88
Garnett	Costilla	7576	114
Grand Junction	Mesa	4602	101
Gunnison	Gunnison	7670	125
Holly	Prowers	3380	108
Lake Moraine	El Paso	10265	93
Lamar	Prowers	3592	117
Lay	Moffat	6190	116
Mancos	Montezuma	6960	96
Meeker	Rio Blanco	6182	105
Montrose	Montrose	5811	107
Pueblo	Pueblo	4734	103
Rocky Ford	Otero	4177	110
Salida	Chaffee	7035	111
Steamboat Springs	Routt	6683	125
Victor	Teller	10100	86
Wagon Wheel Gap Exp. Station	Mineral	9600	86
Westcliffe	Custer	7864	119

Difference Between Air Temperature and That of Soil and Plant Surfaces.—The temperature of soil and plant surfaces during the day usually, not always, exceeds that of the surrounding air. There is an increase in this difference of temperature with elevation above the sea level. High surface temperatures in the mountains, during the time that the sun is shining, compensate in

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a measure for the comparatively short growing seasons, and cool nights. Clements* secured the following results at Minnehaha (altitude 8,400 feet) on Pike's Peak. The air temperature was 75.2°, the surface of the gravel soil 104°, and the surfaces of the plant leaves as follows. *Parmelia* (lichen), 104°; *Eriogonum*, 101.48°; *Arctostaphylos* (kinnikinick), 95°; *Thlaspi* (wild candytuft), 89.24°; and *Senecio*, 87.8°. As is the case with native plants, the temperature of crop plants at high elevations is greater than that of the air about them, the difference depending somewhat upon the transpiring power of the plant considered.

Effect of Exposure upon Air and Surface Temperatures.—By *exposure* is meant direction of slope. A north exposure, for example, *faces* north. The effect of exposure at high altitudes is much more marked than at low elevations. This greater effect is a direct result of the increased rate of radiation at high altitudes. The intensity of sunlight is distinctly affected by exposure and also by degree of slope. A given area of soil or plant surface that is at right angles to the direction of the rays of light will receive much more heat than one upon which the sun's rays fall obliquely, for under the latter condition the rays are spread out over a larger area than when they fall perpendicularly. If we assume the intensity of sunlight to be 100 when it strikes a surface at right angles, its intensity when striking that surface at an angle of 70° will be approximately 98.5; at an angle of 60°, 96.5; and at an angle of 10°, 33.4. Light intensity has its effect upon both air and surface temperatures, which indirectly affect the amount of moisture in the soil, and the relative humidity over the soil. The differences between the native vegetation on adjacnt north and south exposures is so conspicuous in the mountainous sections as to attract the attention of the most inobservant person. In a valley that trends east and west the slope exposed to the south has a much greater total effective heat during the year than the northerly exposure across the valley. The greater light intensity on the south exposure not only results in a warmer, but a drier, habitat than occurs on the neighboring north exposure. A south exposure receives the greatest total heat during the day, the east the next greatest, then the west, and the north exposure least of all. There are numerous examples illustrating the differences between the native vegetation of north and south exposures. In the lower mountain valleys of the north and central parts of Colorado, the south exposures support a semi-arid type of vegetation, composed of cedars, scattered yellow pine (*Pinus scopulorum*), yucca, Colo-

*Research Methods in Ecology, page 71.

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rado candy-tuft (*Thlaspi coloradense*), double bladder-pod (*Physaria didymocarpa*), Indian millet (*Eriocoma cuspidata*), sandwort (*Arenaria fendleri*), oat-grass (*Trisetum montanum*), stipa-grass (*Stipa viridula*), fescue-grass (*Festuca arizonica*), stick-seed (*Lappula occidentalis*), phacelia (*Phacelia leucophylla*), geranium (*Geranium fremontii*), beard-tongue (*Pentstemon humilis*), vetch (*Astragalus shortianus*), and common sage (*Artemisia frigida*). The cooler and moister north exposures are frequently clothed with Douglas fir (*Pseudotsuga mucronata*), aspen (*Populus tremuloides*), Rocky Mountain maple (*Acer glabrum*), spring anemone or pasque flower (*Pulsatilla hirsutissima*), saxifrage (*Saxifraga rhomboidea*), buckbean (*Thermopsis divaricarpa*), bedstraw (*Galium boreale*), and false Solomon's seal (*Vagnera stellata*).

Fig. 4.—In the Wet Mountain Valley. The view is looking due west. Note the bare south exposures and timbered north exposures.

Fig. 4 is a scene in the Wet Mountain Valley, and it shows very clearly the effect of exposure upon local conditions that influence plant growth. The view is looking due west. Douglas fir and white fir clothe the north-facing slope, while grasses and low shrubs dominate the south-facing slope; the two plant communities meet sharply at the crest of the slope. In many of the east-west valleys of the Western Slope, pinyon pine and juniper abound on the warm, dry, south exposures, while Douglas fir and

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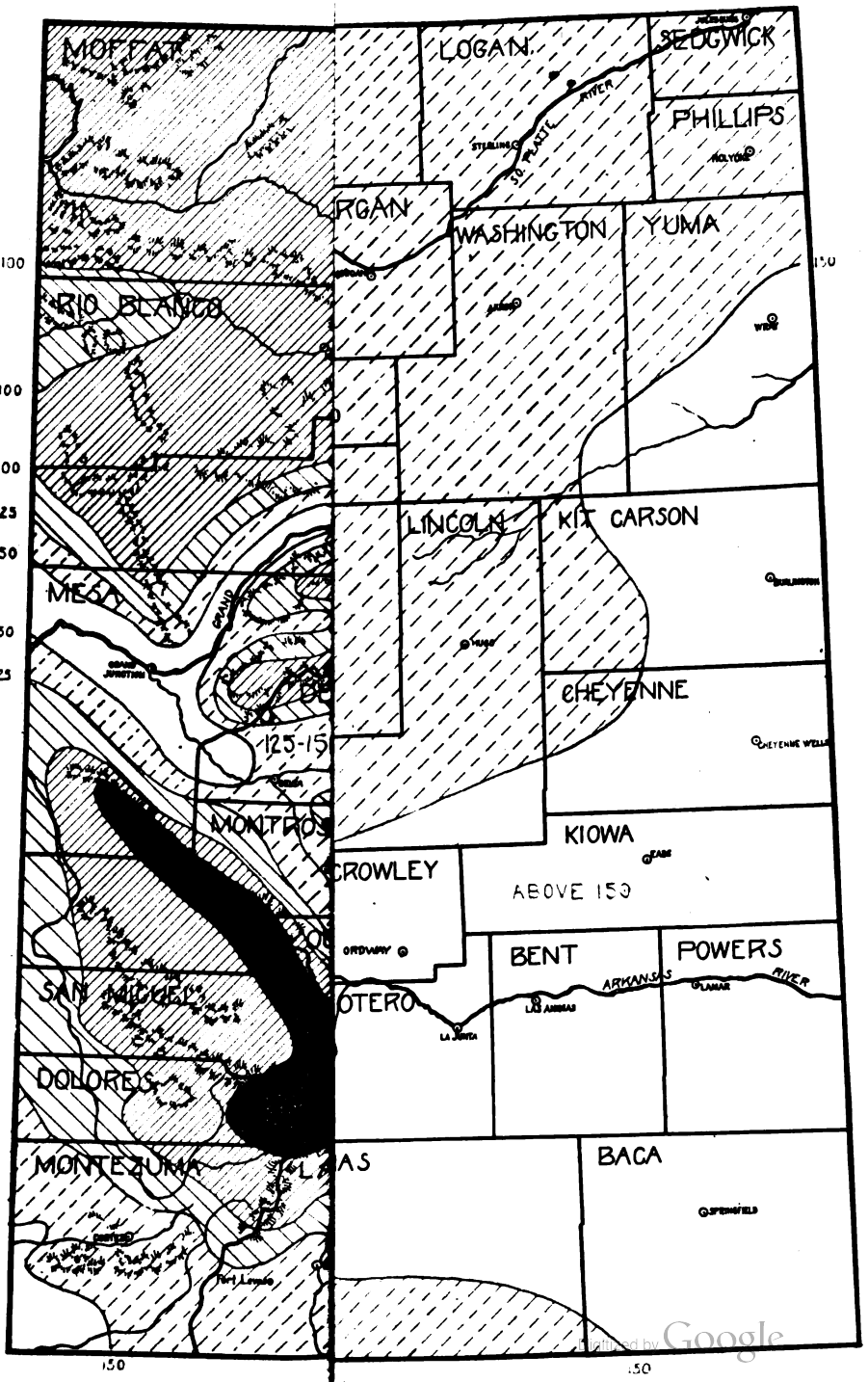
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LINCOLN
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MONTROSE
CROWLEY
KIOWA
ABOVE 150
BENT
POWERS
OTERO
SAN MIGUEL
DOLORES
MONTEZUMA
BACA
ARKANSAS
RIVER
100
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150

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its associates, are to be found on the cooler and moister north exposures.

Plants most abundantly distributed at lower elevations find their uppermost altitudinal limits on warm, south exposures, while plants normally distributed at high elevations reach their lowermost altitudinal limits on cool, moist, north exposures. For example, lodgepole commonly ranges from 8,000 to 10,000 feet, but on southwest exposures may reach 11,000 feet, as it does on Boreas Pass, and quite frequently goes down to 7,500 on cool, north exposures. Timber-line is frequently 1,000 feet, or more, higher on slopes facing south than on those facing north.

The effect of exposure and slope is so marked at high altitudes that great care needs to be exercised in the selection of sites for crop purposes. Alter* emphasizes the significance of slope and exposure in this way: "Likewise, a 5° slope to the south in southern Idaho is in the same solar climate as is a level field in the latitude of southern Utah, 305 miles nearer the Equator."

Throughout the state there are many locally "warm spots", and "warm strips" surrounded by cooler districts. Such locally warm areas owe their higher temperature to topography.

In narrow valleys, shaded slopes may have sometimes an advantage over the sunny ones in the placement of an orchard. Slopes along the south side of narrow valleys that trend east and west may be shaded one or two hours longer each day than the neighboring slope across the stream. As a result of this shadow protection, there may be a delay in the time of blooming, postponing it until the frost danger period is past. On the other hand, on the sunny slope, buds are hastened into activity, possibly to be injured later by frost.

Length of Frostless Season.—"Length of frostless season" as used here means the number of days between the last frost in the spring and the first frost in the fall. From the climatological records it is evident that when the temperature goes to 32°, the day is reported as experiencing a frost. From Tables VII and VIII it is seen that our common fruits are not seriously injured by a temperature of 32° in any stage of their development. However, it must be held in mind that a recorded temperature of 32°, for example, is that of the air 6 feet from the ground, while the air temperature 6 inches from the ground surface is usually 3° to 8° lower. The maps showing length of frostless season and average date of last spring frost enable us to make valuable comparisons, and to better judge of the different localities in the state. Fig. 5 gives the average length of the frostless season for the different

*Crop Safety on Mountain Slopes, U. S. Dept. Agr. Yearbook, pp. 309-318, 1912.

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sections of the state. There is a pronounced variation in the length of this period. Grand Junction has the longest season (average 183 days) of any locality in the state, while on the highest peaks there is no day in the year without frost. Those sections of Colorado with a frostless season averaging above 150 days are the lower Grand Valley, a limited area on the North Fork of the Gunnison about Paonia, the lower McElmo Valley, the Arkansas Valley up as far as Canon City, and an area along the foothills from below Denver to north of Boulder. The tenderer crops are, of course, grown with best success in those sections in which the frostless season averages 150 days or more. However, this statement must not be taken to mean that all portions of the state with a frostless season of 150 days and over are climatically well adapted to tender crops like peaches and apricots, nor that some localities with a slightly shorter average frostless season can not grow such crops with considerable success. There are other climatic conditions besides length of growing season to be considered, for example, coldness and dryness of the winter season, the character of the springs, and total effective heat during the period free from frost. Those stations with a frostless season of 75 days or less are usually such as may experience frost any month of the year. However, over the lower part of this extensive area, which has a growing season averaging less than 75 days, alfalfa, timothy, potatoes, Canada field peas, the small cereals, gooseberries, currants, raspberries, strawberries, and a large list of vegetables are grown with profit.

It is obvious that two stations with the same number of frostless days may have temperature values during this period that differ widely in their effectiveness in determining the rate of plant growth. Daily mean temperatures may be the same, but the maximum and minimum temperatures different. Furthermore, although the number of hours of a day during which the temperature is sufficient to promote plant growth may be the same in two localities, the total effective heat in the two instances may differ widely. Thus it is realized that it is difficult to relate ordinary temperature data, in their usual recorded form, to plant growth; but a number of attempts* have been made to do this in a manner which is more satisfactory than the rough, qualitative method here employed.

*Livingston, B. E., and Livingston, Grace J. Temperature coefficients in plant geography and climatology. Bot. Gaz. 56:349-375. 1913.

MacDougal, D. T. The auxothermal integration of climatic complexes. Amer. Jour. Bot. 1:186-193. 1914.

Livingston, B. E. Physiological temperature indices for the study of plant growth in relation to climatic factors. Physiol. Res. 1:399-420. 1916.

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TABLE V.—FROST DATA FOR REPRESENTATIVE COLORADO STATIONS.
(Data available up to and including year 1915).

Station	County	Altitude in Feet	Average Date Last Spring Frost	Latest Date Last Spring Frost	Average Date First Fall Frost	Earliest Date First Fall Frost	Aver. Length Frostless Seas.	Shortest Frostless Season
Arriba	Lincoln	5240	May 21	June 7	Oct. 4	Sept. 20	133	119
Ashcroft	Pitkin	9483	July 1	July 28	Sept. 1	Aug. 1	61	28
Boulder	Boulder	5347	Apr. 29	May 20	Oct. 12	Sept. 15	166	125
Buena Vista	Chaffee	7955	June 3	June 28	Sept. 20	Sept. 8	108	91
Burlington	Kit Carson	4160	May 3	May 27	Oct. 8	Sept. 25	158	137
Calhan	El Paso	6700	May 15	May 27	Sept. 28	Sept. 2	138	111
Canon City	Fremont	5343	Apr. 28	May 23	Oct. 11	Sept. 17	166	136
Castle Rock	Douglas	6220	May 14	June 10	Sept. 21	Sept. 10	132	99
Cedaredge	Delta	6175	May 16	June 9	Sept. 8	Sept. 10	129	95
Cheyenne Wells	Cheyenne	4279	May 3	May 26	Oct. 6	Sept. 12	157	122
Collbran	Mesa	6000	May 16	June 8	Sept. 26	Sept. 12	132	114
Colorado Spgs.	El Paso	6098	May 6	May 23	Oct. 2	Sept. 11	149	124
Cope	Washington	4250	May 6	May 28	Oct. 5	Sept. 21	150	122
Delta	Delta	4965	May 11	May 28	Sept. 27	Sept. 11	138	113
Denver	Denver	5272	May 4	June 6	Oct. 7	Sept. 13	156	117
Durango	La Plata	6534	May 17	June 5	Sept. 25	Sept. 11	130	98
Ft Collins	Larimer	4985	May 5	May 21	Sept. 26	Sept. 7	144	125
Ft. Morgan	Morgan	4319	May 6	May 25	Sept. 30	Aug. 25	145	95
Frances	Boulder	9300	May 31	June 20	Sept. 20	Aug. 25	110	88
Fruita	Mesa	4510	Apr. 30	May 22	Oct. 3	Sept. 15	156	133
Garnett	Costilla	7576	June 6	July 7	Sept. 12	Aug. 13	95	51
Glenwood Spgs.	Garfield	5823	May 22	June 19	Sept. 18	Aug. 9	112	58
Grand Valley	Garfield	5089	Apr. 3	May 27	Oct. 7	Sept. 11	187	115
Grand Junction	Mesa	4602	Apr. 18	May 14	Oct. 19	Sept. 14	181	144
Greeley	Weld	4649	May 1	May 21	Oct. 1	Sept. 7	156	126
Gunnison	Gunnison	7670	June 28	July 28	Sept. 1	Aug. 1	63	19
Hoehne	Las Animas	5700	May 17	July 4	Oct. 2	Sept. 10	136	73
Holly	Prowers	3380	Apr. 25	May 27	Oct. 11	Sept. 17	166	130
Idaho Springs	Clear Creek	7543	May 20	June 7	Sept. 27	Sept. 13	132	112
Lake City	Hinsdale	8686	June 11	June 24	Sept. 18	Sept. 6	99	80
Lake Moraine	El Paso	10265	June 19	July 24	Sept. 9	Aug. 6	78	52
Lamar	Prowers	3592	Apr. 23	May 14	Oct. 8	Sept. 17	167	140
Las Animas	Bent	3899	Apr. 27	May 20	Oct. 6	Sept. 9	161	123
Lay	Moffat	6190	June 11	July 9	Sept. 5	Aug. 11	85	30
Leadville	Lake	10248	June 17	July 28	Sept. 12	Aug. 2	92	65
LeRoy	Logan	4388	May 3	May 27	Oct. 1	Aug. 25	142	128
Longmont	Boulder	4950	May 3	May 19	Oct. 1	Sept. 15	152	135
Long's Pk (nr.)	Larimer	8600	June 29	July 31	Aug. 30	Aug. 1	62	3
Mancos	Montezuma	6960	June 6	July 6	Sept. 21	Aug. 27	106	78
Meeker	Rio Blanco	6182	June 13	July 4	Sept. 11	Aug. 22	88	57
Montrose	Montrose	5811	May 12	June 8	Sept. 27	Sept. 14	137	113
Moraine	Larimer	7775	June 14	July 26	Sept. 10	Aug. 22	88	57
Pagoda	Routt	6500	May 17	July 19	Aug. 9	Aug. 20	82	55
Pagosa Springs	Archuleta	7108	June 28	July 29	Sept. 12	Sept. 5	78	58
Paonia	Delta	5694	Apr. 30	May 20	Oct. 16	Sept. 21	161	130
Pueblo	Pueblo	4734	Apr. 27	May 23	Oct. 7	Sept. 12	163	139

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TABLE V.—FROST DATA FOR REPRESENTATIVE COLORADO STATIONS.—CONT.
(Data available up to and including year 1915).

Station	County	Altitude in Feet	Average Date Last Spring Frost	Latest Date Last Spring Frost	Average Date First Fall Frost	Earliest Date First Fall Frost	Aver. Length Frostless Seas.	Shortest Frostless Season
Rangely	Rio Blanco	5050	May 16	June 28	Aug. 21	Aug. 31	115	88
Rocky Ford	Otero	4177	Apr. 27	May 15	Oct. 8	Sept. 13	164	140
Saguache	Saguache	7740	May 26	June 18	Sept. 25	Sept. 10	124	93
Salida	Chaffee	7035	May 26	July 6	Sept. 17	Sept. 6	113	68
San Luis	Costilla	7794	July 5	July 6	Sept. 20	Sept. 5	106	68
Sapinero	Gunnison	8125	June 17	June 30	Sept. 15	Sept. 6	91	81
Silverton	San Juan	9400	June 3	July 9	Aug. 8	Aug. 26	65	55
Spicer	Jackson	8700	June 27	July 11	Aug. 27	Aug. 31	61	34
Steamboat Spgs.	Routt	6683	July 7	July 30	Aug. 30	Aug. 2	57	24
Sterling	Logan	3892	May 6	May 22	Sept. 27	Sept. 5	144	127
Sugar Loaf	Boulder	7800	May 25	June 14	Sept. 18	Aug. 25	116	93
Telluride	San Miguel	8756	June 29	July 27	Sept. 5	Aug. 18	74	66
Trinidad	Las Animas	5994	May 1	May 28	Oct. 11	Sept. 22	162	133
Victor	Teller	10100	June 4	July 8	Sept. 21	Sept. 5	111	76
Wagon Wh. Gap.	Mineral	9610	July 11	July 31	Aug. 19	Aug. 1	25	1
Walden	Jackson	8050	July 6	July 20	Aug. 31	Aug. 14	56	25
Westcliffe	Custer	7864	July 10	July 29	Oct. 14	Aug. 1	101	67
Whitepine	Gunnison	9500	June 3	July 9	Aug. 7	Aug. 22	64	46
Wray	Yuma	3512	May 6	May 27	Oct. 3	Sept. 12	150	124

Variations in Frost Dates and Length of Frostless Season.—It is of value to know the frequency of late frosts in the spring, of early frosts in the autumn and also of short frostless seasons.

Variation in the length of frostless seasons for a number of Colorado stations is shown in Fig. 6. In some localities, there is not much departure from the normal from year to year, and the farmer or fruit-grower finds the seasons much the same from year to year, while in other localities there is very marked variation, which leads to much uncertainty and uneasiness on the part of the farmer or fruit-grower.

Effect of Altitude on Length of Frostless Season.—The average length of the frostless season for all stations in the different altitudinal zones is shown in the accompanying table.

TABLE VI.—ALTITUDE AND LENGTH OF FROSTLESS SEASON.

Feet	Days
Below 5000	146
5000—6000	138
6000—7000	113
7000—8000	98
8000—9000	56

A pronounced difference exists between the average length of the frostless season of stations having approximately the same

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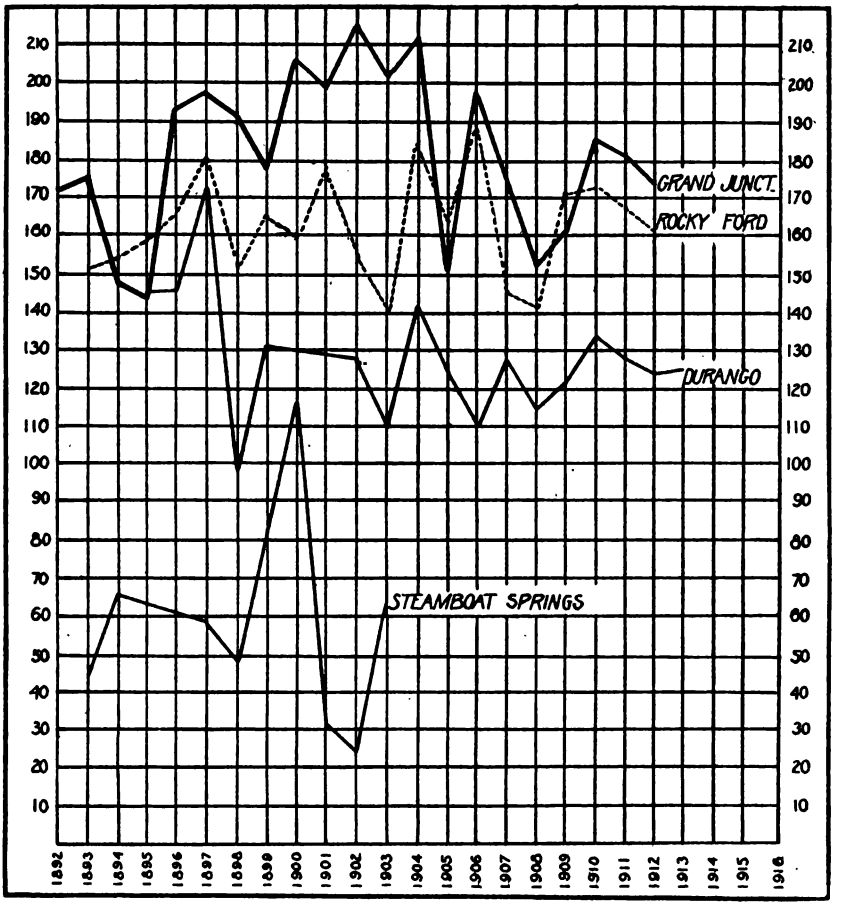

Fig. 6.—Variation in length of frostless seasons for Grand Junction, Rocky Ford, Durango, and Steamboat Springs.

altitude, but located differently topographically. A few examples will illustrate this point: Castle Rock (altitude 6,220 feet), has an average frostless season of 98 days, Cedaredge (altitude 6,175 feet), 127 days; Conejos (altitude 7,880 feet), 128 days; Westcliffe (altitude 7,864 feet), 106 days; and Pagosa Springs (altitude 7,100 feet), 85 days.

Frosts.—The formation of frost and the factors conditioning it are quite well known. Plants lose their heat by radiation to the surrounding air. In fact, radiation is more rapid from plant surfaces than from the surrounding air. If the temperature of the plant surface is lowered far enough, the water vapor of the sur-

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rounding air condenses on the plant, and, if further lowering of the temperature takes place, the condensed vapor freezes, and "frost" is formed.

The rate of radiation of heat from a plant surface is increased and hence the formation of frost favored by the following conditions: (1) Clear sky; (2) dry air; (3) still nights; (4) rare atmosphere (as at high altitudes). Clear nights are the rule in Colorado, and hence the radiation at night is pronounced. A blanket of fog or clouds tends to retard the loss of heat from bodies on the earth's surface. The actual amount (not relative amount) of water vapor in the air decreases with altitude, and since water vapor absorbs and retains heat radiated from the earth's surface, the atmosphere at high altitudes is less able to hold this heat than atmosphere at lower elevations. It is a common observation that frosts are more prevalent on still nights than when the air is in motion. Radiation of heat proceeds with greater rapidity in a rare atmosphere, such as is found at high altitudes, than it does in a dense atmosphere, such as is found at low elevations.

Freezing of Plants.—In the freezing of plant tissues, injury may result in two ways: (1) Water may be withdrawn from the plant cells and ice crystals from this water form in the spaces between cells; subsequently the ice in the intercellular spaces may evaporate, and cause death of the plant tissue by drying out. It is well-known that many plants may survive extremely cold weather provided it is not accompanied by a dry atmosphere; (2) again, the injury from low temperatures may result from the actual freezing of the cell sap, which may cause a mechanical rupture of the living material in the cell itself.

It is a familiar observation that some of the more tender plants are injured by temperatures above the freezing point; and that, on the other hand, there are many plants that may withstand temperatures considerably below the freezing point. This statement may apply not only to dormant plant parts, but to swelling buds, open flowers, and forming fruit as well. The plants at timber-line and above are subject to freezing temperatures almost every night in the year. The exact nature of this immunity to low temperatures is not known.

There are remarkable differences between varieties of plants, between individuals of the same variety, and even between different buds on the same tree, in their resistance of low temperatures. This resistance may depend much upon the age of the tissue, and the treatment and care the plant has had during its life. Old plant tissue is more resistant than newly-formed tissue. A pruning prac-

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tice that stimulates the production of tender shoots and a cultural method that favors the development of succulent tissue may result in more or less freezing. Temperature conditions preceding and leading up to a freeze are important in influencing the resisting power of a plant. A series of warm days preceding a freeze, which permits the formation of many new plant cells, with their thin walls and an abundance of water, is especially injurious. Such warm days are prevalent in Colorado, coming even weeks ahead of the last frost. During a favorable spring, the minimum and maximum temperatures, as well as the mean, for the 24 hours of the day, should become gradually greater. Under such circumstances, even though the warm days induce the swelling of buds, they are better able to undergo the low temperatures of the nights. An unfavorable spring is one whose maximum, minimum and mean daily temperatures fluctuate greatly. Many mountain valleys are so shaded during a portion of the day that fruit buds are delayed in opening. A shaded mountain slope is quite likely to have daily extremes of temperature that are much less than those of a sunny slope. The latter warms up rapidly and to a high point in the day time, and at night cools as rapidly, and reaches as low a temperature as its neighboring shaded slope. Furthermore, if there be any efficacy in the gradual thawing of frosted plant tissues, mountain shadows will be of value in retarding the rate of this process.

In the Monthly Weather Review for March, 1912, are published data showing temperatures injurious to peaches, apples and pears in various stages of development. The data were compiled by a committee appointed by the Fruit Growers' Association of the Grand Valley, Colorado. The tables (VII and VIII) are taken verbatim from the Monthly Weather Review.

TABLE VII.—SHOWING AT WHAT TEMPERATURES SMUDGING IS NECESSARY IN THE VARIOUS STAGES OF DEVELOPMENT OF PEACH BUDS.

	Degrees
Peaches ¼ inch in diameter	30
Dropping the shuck	31
Setting	31
Full bloom	29 to 30
Buds in pink	22
Buds swelling	15
Buds dormant	15

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TABLE VIII.—SHOWING AT WHAT TEMPERATURES SMUDGING IS NECESSARY IN THE VARIOUS STAGES OF DEVELOPMENT OF APPLE AND PEAR BUDS.

	Degrees
Calyx closed	30
Flowers gone, calyx closing	30
Petals dropping	31
Fruit forming	30
Full bloom	30
Buds in pink	25
Buds separating	20
Buds swelling	15

From the two tables above, it is evident that a temperature of 32°, which may be accompanied by the formation of frost, is not low enough to cause injury to our fruits in any stages of their development. It very frequently happens that the temperature just touches 32°, not going lower, and after remaining there for a short time, becomes higher.

Average Date of Last Spring Frost.—Fig. 7 shows the average date of the last spring frost in the different sections of Colorado. In a few localities the average date is before May 1. Over the greater part of the Great Plains it is between May 10 and May 20. Throughout the entire mountainous parts of the state above about 7,000 feet, and also at lower altitudes in the northwest counties, the average date is after June 1.

Inversion of Temperature.—As a rule, temperature decreases with an increase in altitude. Occasionally, however, as a result of air drainage, the valleys and canyon bottoms are cooler than the adjacent hillsides; in other words, temperature may increase locally with altitude. Temperature inversion is a common phenomenon in mountainous regions, and is particularly noticeable in the spring and autumn.

A comparative study* of temperatures on two mesas near Boulder, with a difference in elevation of 415 feet, showed for May, 1908, the mean monthly temperature to be 2.6° higher on the upper mesa than on the lower. Furthermore, the last frost in the spring was 16 days later on the lower mesa than on the upper one. This inversion is undoubtedly present all along the foothills and in many other sections of the state, not occurring every year, but to be expected.

At certain periods, inversion of temperature of more than local influence occurs along the eastern edge of the foothills, which up to a considerable altitude experience a higher temperature than the plains. Loud† points out that on the eastern slope of the

*Ramaley, Francis. Climatology of the mesas near Boulder, Colo., in Studies on mesa and foothill vegetation. Univ. Colo. Studies 6:11-49. 1909.

†Loud, F. H., The Colorado Sky 1:1-9. 1908.

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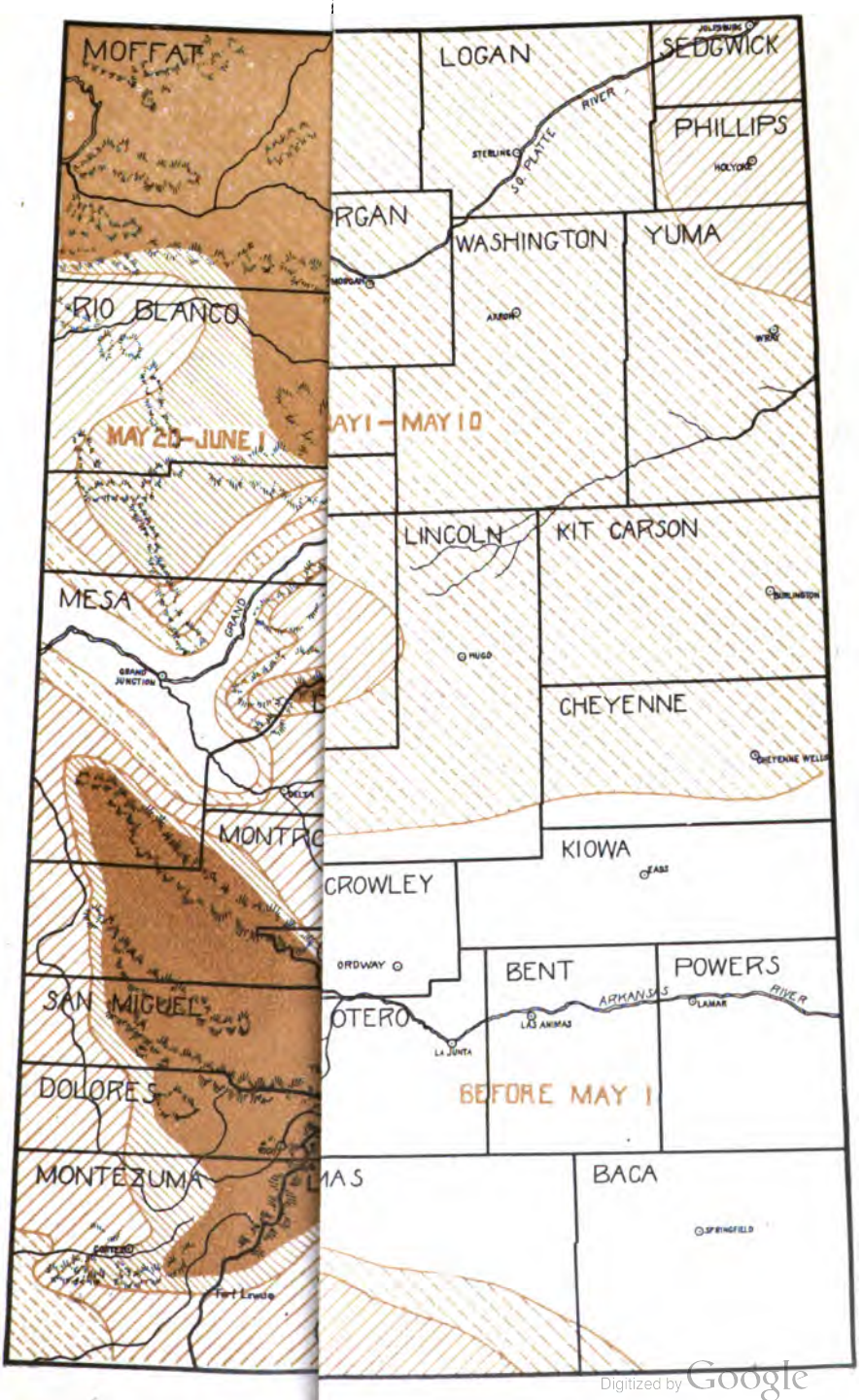

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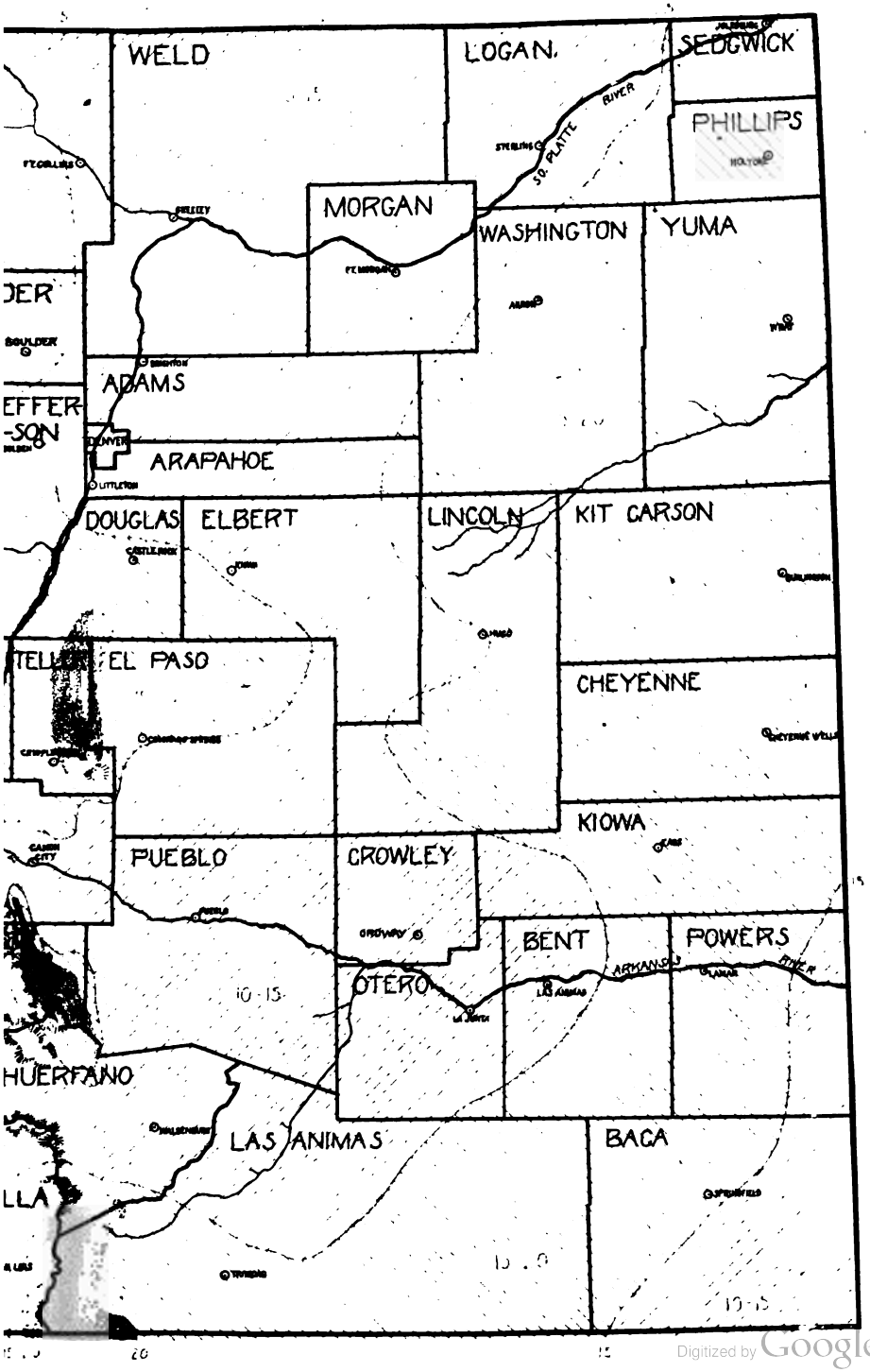

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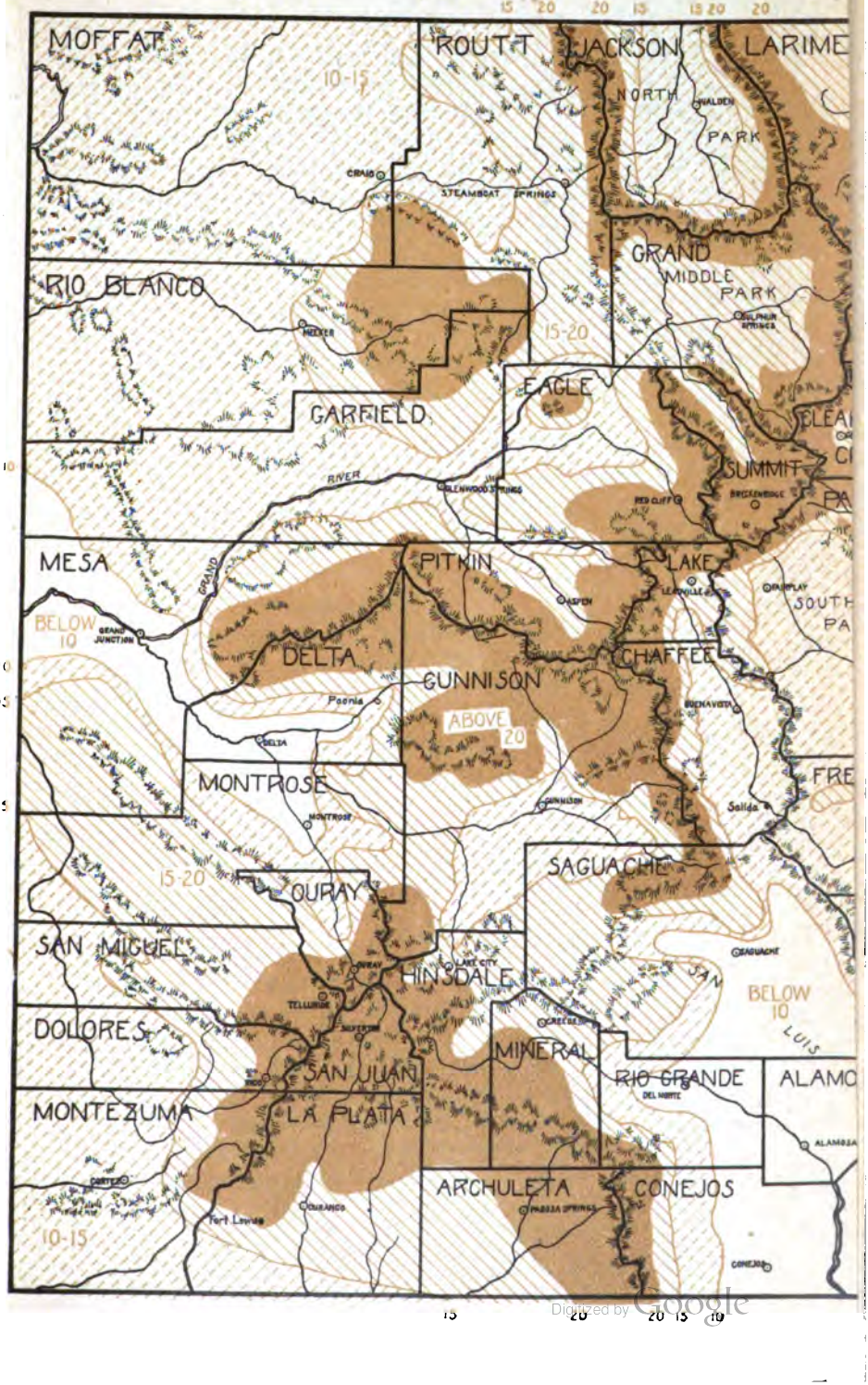
FIG. 8. MEAN AN



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Rocky Mountains in Colorado he has often noticed that elevated stations retain a mild temperature for some time after a cold wave has set in at a lower level. Marked temperature inversion has been observed in the orchard sections of western Colorado. As pointed out on page 8, the mean temperature for January, 1915, at Marble (7,951 feet) was 6° higher than at Glenwood Springs (5,758 feet) in the same drainage system, and that at Cedaredge (6,175 feet) was 3.9° higher than at Delta (5,025 feet).

Batchelor and West* have shown, in the neighborhood of Logan, Utah, that "The minimum temperatures experienced by the brush lands, and upper slopes of the tillable area in a mountain valley average from 6° to 10° warmer than the valley bottoms, due to the drainage of cold air to the low areas during the typical clear, calm, frosty nights".

Temperature inversion is largely eliminated by cloudiness and by wind movement. Temperatures are not as low at the mouths of canyons where canyon breezes exert an influence, as they are at stations of about the same elevation which are not under the influence of these breezes.

PRECIPITATION

Mean Annual Precipitation.—In making a mean annual precipitation map of Colorado it is found difficult to depend entirely upon rain-gage records, for in some sections of the state stations are so very far apart and the topographical conditions between them may be so varied as to indicate quite clearly that the rainfall and snowfall are much different in amount from that indicated by the nearest stations. Therefore, in the construction of the precipitation map (Fig. 8), not only were all available records taken into account, but the directions of lines at intermediate points were guided by topography, and by the character of the native plant associations.

The portions of Colorado with an average annual precipitation less than 10 inches include most of the San Luis Valley and the lower altitudes in the Grand and Uncompaghre drainages. A large percentage of Colorado has an annual precipitation between 10 and 15 inches. This includes the western half of the Great Plains lying next to the foothills, a corner in the southeast, much of South Park and the Wet Mountain Valley, most of North Park, almost all of the northwest counties, intermediate elevations in the western valleys, lower altitudes in Montezuma, Dolores and

*Batchelor, L. D., and West, F. L. Variation in minimum temperatures due to the topography of a mountain valley in its relation to fruit growing. Utah Agr. Exp. Sta., Bul. 141:1-27. 1915.

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San Miguel counties, and a strip bordering San Luis Valley. The 15-inch precipitation line follows quite closely the 6,000-foot contour line along the eastern mountain front and the 7,000-foot line in the western portion of the state, except in the Gunnison district where it is elevated to 8,000 or 8,500 feet. The 15-inch line runs at an altitude of about 9,500 feet in the Wet Mountain Valley, North Park, and San Luis Valley. The eastern half of the Great Plains and also a strip along the southern border, except the corners of Baca and Prowers counties, experience 15 to 20 inches of precipitation on the average, which gives this section an advantage over the western half of the Plains in dry land agriculture. The 20-inch isohyetal line varies in altitude from about 8,500 feet to 10,000 feet. The higher elevations in the state have over 20 inches of rainfall. Although there are localities with an annual precipitation considerably over 25 inches, there are too few stations to enable one to put in the 25-inch line with any degree of accuracy.

In connection with this discussion, it should be pointed out that the total precipitation for the year may not give us a true idea of the effectiveness of such in increasing the moisture content of the soil, and in influencing plant growth. In addition, we need to know particularly the distribution of the precipitation throughout the year, and the frequency and nature of the same. For example, torrential rains, although they swell the total annual amount, may run off in large part as flood waters, and only a small fraction be left in the soil for plant use. Again, frequent light showers, followed by sunny skies, may moisten merely the surface of the soil, and the moisture be carried away shortly; moreover, light showers may effect the formation of a surface crust on the soil, which may actually be harmful in that it establishes a capillary connection with the soil below, and moisture from these lower layers is lost to the air. The minimum effective amount of rainfall will not be the same for different soil types, or for similar soil types when atmospheric conditions vary. Light showers followed by cloudy weather are more beneficial than when followed by bright, sunny weather.

Variation in Precipitation from Year to Year.—Very wet and very dry years, or a consecutive series of these, are not uncommon in Colorado. The mean difference between the wettest and driest years is somewhat greater for localities east of the Continental Divide than for localities west. The following brief table gives one an idea of this fluctuation.

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TABLE IX.—GREATEST AND LEAST YEARLY PRECIPITATION (INCHES).

Station	No. of Years Considered	Greatest	Least
Cheyenne Wells	16	25.46	9.72
Cowdrey, North Park	19	21.27	10.01
Denver	42	22.96	7.75
Durango	16	34.29	8.90
Fort Collins	32	22.79	7.11
Garnett	17	9.82	3.50
Grand Junction	19	11.61	3.64
Hamps	18	24.15	7.63
Meeker	17	24.30	12.67
Long's Peak (near)	20	29.66	13.50
Rocky Ford	22	18.75	6.93
Wray	17	26.99	10.74
Yuma	20	29.29	10.26

The variation in precipitation from year to year for a number of localities is shown graphically in Fig. 9.

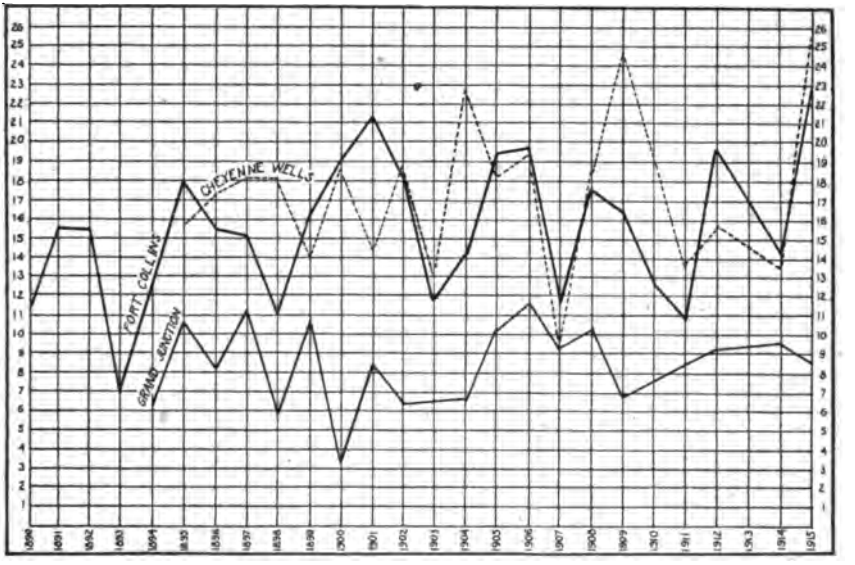

Fig. 9.—Variation in total precipitation from year to year for Cheyenne Wells, Fort Collins, and Grand Junction.

Distribution of Rainfall Throughout the Year.—There are several distinct types of rainfall in Colorado. The Great Plains section is characterized by a rainfall, about 75% of which occurs during the growing season, and 50% to 74% of which may come during the months of June, July, August, and September. This section has two main types of rainfall. In the region north of the Arkansas-Platte Divide, comprising the South Platte drainage sys-

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tem, the rainy months are April and May, with the exception of a few localities in Yuma and Phillips counties, where the maximum usually comes in June. The Arkansas-Platte Divide and the entire Arkansas Valley receive their maximum rainfall during the summer, July showing the greatest monthly amount.

July and August are the wettest months throughout the San Luis Valley. The same months are usually the wettest in the valleys of the Las Animas, La Plata, Mancos and McElmo. Over practically the whole of the western slope, the spring is wetter than the other seasons, and there is quite wide variation as to the month that shows the greatest precipitation, although July and August are usually the wettest. In North Park, March and April are usually the two rainiest months. April and May are normally quite rainy months on the mountains of the eastern slope; this period is followed by a relatively dry June, and then July and August, with their afternoon showers, show large monthly amounts. July is usually the month of greatest rainfall in the Wet Mountain Valley.

The marked differences in the seasonal distribution of precipitation east and west of the Continental Divide are worthy of special mention. East of the Divide the greater part of the total precipitation for the year comes during the growing season, when plant life can use it. On the other hand, west of the Continental Divide only about one-half of the yearly amount comes during the growing season; here from 30% to 50% of the total for the year falls during the four months, June, July, August and September. Although the Western Slope has not the advantage of spring rainfall, this is offset in a measure by its greater snowfall, and by the presence of a ground cover of snow a good part of the winter season.

Increase of Precipitation with Increase of Altitude.—It may be stated as a general rule that rainfall increases in amount and frequency with elevation above the sea level. There are, of course, exceptions which are due to topography. For example, the average yearly precipitation for Saguache (altitude 7,740 feet) in the San Luis Valley is 7.39 inches, while that for Pueblo (altitude 4,734 feet) on the plains is 11.67 inches. The low precipitation of San Luis Valley stations, although at considerable elevations, is due to their almost complete enclosure by high mountain ranges. There is wide variation in the rate of increase. It may require as little as 200 feet or as much as 1,200 feet increase in altitude to give an increase of one inch of precipitation.

Snowfall.—The annual snowfall throughout the state varies as widely from year to year as does the annual precipitation as a

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whole. A low amount of snowfall may be due to a normally low precipitation for the year as a whole, or to an unequal distribution of the precipitation of a locality that shows a considerable annual amount. For example, the average annual snowfall in the San Luis Valley ranges from 7 to 30 inches. This small amount is to be expected, as the total precipitation (rainfall plus snowfall) for the year is below 10 inches. However, on the Great Plains, where the total snowfall averages less than 30 inches, (Limon 18, Holly 13, Blaine 23, Las Animas 24, Pueblo 23, Ft. Morgan 25), the low figure is explained by the fact that about 75% of the yearly precipitation comes during the growing season.

In general, the amount of snowfall increases at higher altitudes. The mean total snowfall for the year at some typical high altitude stations is as follows:

TABLE X.—MEAN ANNUAL SNOWFALL.

Station	Altitude (feet)	Mean Annual Snowfall (inches)
Ashcroft	9482	148
Breckenridge	9536	199
Corona	11660	377
Crested Butte	8867	158
Cripple Creek	9400	84
Frances	9300	175
Georgetown	8550	94
Lake Moraine	10265	151
La Veta Pass	9000	107
Leadville	10248	132
Long's Peak (near)	8600	127
Rico	8824	148
Silverton	9400	169

The snowfall in northwestern Colorado is high. At Meeker the average in inches is 66, at Buford 86, Pagoda 105, Hayden 81, Yampa 71, and Steamboat Springs 119. It is also quite high in North and Middle Parks; for example, Walden and Spicer, each in North Park, have about 70 inches, and in Middle Park, Kremmling has 110 inches, Hot Sulphur Springs close to 100 inches, and Fraser 104 inches. There is also an abundance of snowfall in the southwest. At Durango the average is 62 inches; at Tacoma, 87; Pagosa Springs, 84; and Chromo, 102.

On the plains and the lower slopes of the eastern part of Colorado, snows do not, as a rule, lie on the ground for any length of time, but disappear within a few days, and vegetation is without the protection which snow offers. On the western slope, however, the snows accumulate, not only protecting the vegetation but furnishing the soil with a supply of moisture that is not often exhausted until in July. The dry, open winters of the Great Plains, with the absence of a protecting snow cover, are often detrimental

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to such plants as alfalfa. The wind movement in the winter bears a relation to plant growth. For example, there is ample snowfall in North Park, but the winds pile the snow into drifts, sweeping it from the level places. The exposure to the low temperatures thus brought about often makes conditions unfavorable for the wintering over of alfalfa, strawberries, etc.

HUMIDITY

The rate of water loss from the surfaces of plants is largely determined by the relative humidity of the atmosphere. The higher the relative humidity, that is, the nearer the air is to the point of saturation, the less rapid the rate of water loss (transpiration); the lower the relative humidity, the more rapid is the loss of water. For example, a plant growing in an atmosphere with a relative humidity of 50% will lose water at a much greater rate than one in the same kind of atmosphere having a relative humidity of 60% or 70%, providing other environmental conditions are approximately the same.

The relative humidity of the atmosphere is affected by the following conditions: 1. *Temperature.*—In two regions, each with the same precipitation, the warmer has the lower relative humidity, that is, is drier. High temperatures increase the capacity of the air for moisture, and hence decrease the relative humidity. The relative humidity of the air falls during the day, and rises during the night. It is nearly always higher at 6 a. m. than at 6 p. m. For example, a ten-year average of the relative humidity at Denver for the year at 6 a. m. varies from 61% to 70%, and at 6 p. m. from 37% to 48%. 2. *Wind.*—The relative humidity is less in a region where high winds prevail. Winds have a pronounced drying effect. Winds are particularly injurious to plants that have parts of them exposed during the winter season, for then the cold soil retards the intake of water by the roots, and the rate of intake does not keep pace with the rate of outgo. It is well to remember that the bare stems of fruit trees, the bare canes of raspberries, currants, blackberries and gooseberries, the crowns of alfalfa, and of strawberries, are losing some water throughout the winter period. Winter killing of fruit trees, cane fruits, and alfalfa in Colorado is not the result of low temperatures alone, but of the combined effect of low temperatures and a dry atmosphere. Plants are particularly sensitive to winter cold if the air is dry. 3. *Air Pressure.*—Other factors remaining constant, a decrease in the air pressure lowers the relative humidity. 4. *Exposure.*—South exposures, with their greater heat, have a lower relative humidity than north exposures. Moreover, slopes exposed to the

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wind experience a lower relative humidity than those protected. 5. *Cloudiness.*—Clear, sunny winters are dry, and are usually much more unfavorable to resting plants than cloudy winters.

The intensity of evaporation throughout Colorado is generally great, that is, the relative humidity is low, or in other words, the air is dry. Hence the plants are making a strong demand for water from the soil. The following data from Bulletin 182, Colorado Agricultural Experiment Station, show the average evaporation from a free water surface at Ft. Collins.

TABLE XI.—AVERAGE EVAPORATION IN INCHES FROM FREE WATER SURFACE, FT. COLLINS.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1.3	1.59	2.88	4.26	4.62	5.37	5.58	5.00	4.30	3.32	1.54	1.14	40.9

The amount of water evaporated from a free water surface, at Ft. Collins, increases from winter to spring and summer, reaching its maximum in July. The evaporation from a dry or medium dry soil surface is less than that from a free water surface, while evaporation from a wet soil surface is about the same as that from a free water surface.

The monthly evaporation during June, July and August is heavy, and although these months are not rainless, the rainfall does not have as much effect upon plant life as that coming in April and May, which months have a lighter evaporation.

There is a decrease in the absolute amount of water vapor in the atmosphere with an increase in altitude. But there is no constant and regular relation between relative humidity and altitude. However, high elevations are subject to an extremely dry atmosphere, which results in excessive water loss from soil and plant surfaces. The periods of excessive dryness come in clear weather, accompanied by high winds, both during the warm and cold seasons. A low relative humidity, which means an increased rate of evaporation, is especially pronounced in the elevated, open mountain valleys, and on south exposures.

SUNSHINE

Colorado is a state with ample sunshine. The percentage of possible sunshine is higher in the mountain states than in the more humid sections of the country. The following table will give the reader an idea of the amount of sunshine in Colorado as compared with other stations throughout the United States.

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TABLE XII.—PERCENTAGE POSSIBLE SUNSHINE AT DIFFERENT POINTS IN THE UNITED STATES.

Station	Percentage Possible Sunshine
Albany, N. Y.	48
Amarillo, Texas	78
Atlanta, Georgia	58
Baltimore, Md.	59
Boston, Mass.	58
Chicago, Ill.	58
DENVER, COLORADO	65
Dubuque, Ia.	57
DURANGO, COLORADO	75
GRAND JUNCTION, COLORADO	67
Indianapolis, Indiana	55
LaCross, Wis.	56
Memphis, Tenn.	62
New Orleans, La.	58
Omaha, Neb.	59
PUEBLO, COLORADO	76
Richmond, Va.	60
St. Louis, Mo.	58
San Diego, Cal.	68
Santa Fe, New Mexico	75
Tacoma, Washington	38
Yuma, Arizona	88

The average percentage of possible sunshine for the four Colorado stations in the table above is 70.7. This percentage is lower at most high elevations, except the large highland parks, such as San Luis, Middle and North.

EFFECT OF INCREASE IN ALTITUDE UPON CLIMATIC FACTORS

Mention has been made of the great range of altitude in Colorado. All are familiar with the fact that an increase in altitude brings about changes in the factors which make up our climate, and which operate upon plants. However, altitude must not be considered as a single environmental factor, like precipitation, or light, or humidity. An increase in altitude generally brings with it a number of changes in environmental factors. The principal changes resulting from an increase in altitude are as follows:

1. Decrease of Air Pressure.—The amount of this decrease may be judged from the following table. Atmospheric pressure is affected slightly by temperature; in the table a temperature of 68° is taken. (Table modified from Hann's Handbook of Climatology.)

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TABLE XIII.—DECREASE OF AIR PRESSURE WITH ALTITUDE.

Altitude (feet)	Air Pressure (inches)
0	30
1640.42	28.307
3280.8	26.693
4921.2	25.157
6561.7	23.622
8202.1	22.283
9842.5	20.905
11482.9	19.724
13123.3	18.504
16404.2	16.339

Providing other factors remain the same, a decrease in the atmospheric pressure increases the rate of evaporation. Furthermore, radiation of heat increases in intensity with an increase in the rarity of the atmosphere. Hence, as a result of the increased rate of radiation, and of evaporation at high altitudes, objects cool off very rapidly, the formation of frost is favored, and the length of the growing season is shortened.

2. Decrease of air temperature.—As a rule, in Colorado, an increase in elevation of 1,000 feet decreases the mean temperature for the year about 2½°, spring 3½°, summer 3°, fall 2½°, and winter 1½°. (Page 7).

3. Decrease in the difference between the mean temperature of the warmest month and that of the coldest month.

4. Greater difference between sun and shade temperatures page 9).

5. Greater difference between day and night temperatures page 9).

6. Increase in heating effect of the sun (page 9).

7. Increase in the difference between the temperature of soil and plant surfaces and that of the surrounding air (page 10).

8. Increase in the effect of exposure (page 11).

9. Shortening of the growing season (page 13).

10. Increase in precipitation (page 24).

11. Decrease in absolute amount of moisture in the air (page 27).

12. Increase in the rate of evaporation (page 27).

13. Stronger wind movement.—However, the rate of wind movement is very dependent upon local topographic conditions, such as direction of mountains, and exposure.

14. Increase in the intensity of ultra-violet rays.

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SUMMARY OF CHARACTERISTIC FEATURES OF COLORADO CLIMATE, ESPECIALLY THOSE THAT BEAR UPON AGRICULTURE

1. Great variation throughout the state. We have a variety of climates such as one would pass through in going from Virginia to Greenland within the Arctic Circle. This variation necessitates the development of special crops, and special varieties, for the different climatic districts.

2. Low precipitation in districts where temperature conditions are most favorable for crops, hence necessity for irrigation.

3. Short growing season in regions with considerable precipitation.

4. Extremes of heat and cold, both diurnal and annual, especially on the plains, in the upland valleys, and in the western section of the state.

5. Cool nights and warm days.

6. Frequent late spring and early fall frosts, that is, a great variation from year to year in the length of the growing season.

7. High winds which, together with low winter temperatures, have much to do with winter killing.

8. Comparatively low relative humidity throughout the year, resulting in rapid loss of water from plant surfaces. The absence from Colorado of many fungous diseases is in part due to the low relative humidity of its atmosphere.

9. Wide variations from the normal as regards almost all climatic factors.

NATIVE VEGETATION

Chief Native Plant Communities*.—No attempt will be made here to give a full discussion of all the native plant communities in Colorado. Only those that cover large areas, or are in the main climatically determined, will receive attention. However, as has been stated, the character of a plant covering is a response to local as well as climatic factors, and it is difficult to distinguish the relative effects of the two sets of factors.

The following large communities of Colorado native plants, with their climatic and agricultural relations, are discussed:

1. Grass-steppe or short-grassland (Great Plains).

2. Shrub-steppe. Sagebrush, greasewood, rabbitbrush, etc.

*The term "community" is used here in a general, unrestricted sense to include any aggregation of plants, such as grassland, oakbrush chaparral, yellow pine forest, etc., regardless of its vegetational rank.

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3. Chaparral or brushland (thicket). Oakbrush, buckbrush, willow thicket, chokecherry, thornapple, mountain mahogany, etc.
4. Coniferous woodland. Pinyon pine and juniper woodland.
5. Coniferous forests.
   a. Yellow pine-Douglas fir forest.
   b. White fir forest.
   c. Lodgepole pine forest.
   d. Engelmann spruce-balsam fir forest.

It is realized that some of the above groups, particularly greasewood shrub-steppe, and chaparral, have a wide range of climatic conditions, and are called forth by local factors to a large degree, but they are such prevalent types of vegetation in the state, that they are included here and the range of their factors given.

Altitudinal Zones of Vegetation in Colorado.—Altitudinal vegetation zones or belts in the state are quite clearly recognized. As one travels from the sage plains of western Colorado, or from the grass plains of the eastern section of the state, to the crest of the Continental Divide, he passes through quite distinct and often sharp belts of vegetation. Realizing the changes in the supply of moisture, in the temperature, and in other environmental factors that accompany an increase in altitude, one is led to suspect that the different vegetation belts are a response to these factors, and, furthermore, that the presence of this or that dominating plant group might be correlated with crop possibilities. At least, it is believed possible to establish the broader and more general correlations.

NORTHEASTERN COLORADO

1. Plains (grass-steppe or short grassland). Up to 6,000 feet.
2. Chaparral or brushland of chokecherry, thornapple, mountain mahogany, etc. A narrow, interrupted belt.
3. Yellow pine-Douglas fir zone. 6,000-8,000 feet.
4. Lodgepole pine zone. 8,000-10,000 feet.
5. Engelmann spruce-balsam fir zone. 10,000-11,500 feet (timber-line).
6. Alpine zone. Above timber-line.

SOUTHEASTERN COLORADO

1. Plains. Up to 5,500 or 6,000 feet.
2. Pinyon pine-juniper zone. 5,500 or 6,000-7,000 feet. Oak chaparral is frequently an associate.
3. Yellow pine-Douglas fir zone. 7,000-8,500 feet.

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4. White fir zone. 8,500-10,000 feet.
5. Engelmann spruce-balsam fir zone. 10,000-11,500 feet.
6. Alpine zone. Above timber-line.

SAN LUIS VALLEY

1. Shrub-steppe, chiefly greasewood and rabbitbrush. 7,500-8,000 feet.
2. Pinyon pine-juniper zone. 8,000-8,500 feet.
3. Yellow pine-Douglas fir zone. 8,500 or 9,000-9,500 feet.
4. Lodgepole pine zone. 9,500-10,000 or 10,500 feet. Lodgepole pine is rare on the eastern side of the Valley. White fir may here take its place.
5. Engelmann spruce-balsam fir zone. 10,000 or 10,500—timber-line.
6. Alpine zone. Above timber-line.

SOUTHWESTERN AND MIDDLE-WESTERN COLORADO

1. Shrub-steppe. Sagebrush. Best developed under 7,000 feet, but frequently running up to 9,500 feet in warm valleys.
2. Pinyon pine-juniper zone. A belt of varying vertical width.
3. Yellow pine-Douglas fir zone. 7,000 or 7,500-8,000 or 8,500 feet. Douglas fir frequently goes much beyond the limits of yellow pine. Aspens well developed.
4. Engelmann spruce-balsam fir zone. Up to timber-line.
5. Alpine zone. Above timber-line.

NORTHWESTERN COLORADO

1. Shrub-steppe. Sagebrush. Up to 6,000 or 7,000 feet.
2. Chaparral, chiefly of oak and buckbrush. 6,000 or 7,000-8,000 feet.
3. Lodgepole pine zone. 8,000-10,000 feet. Aspens abundant.
4. Engelmann spruce-balsam fir zone. 10,000-11,500 feet.
5. Alpine zone. Above timber-line.

In Middle and North Parks the zone immediately bordering on sagebrush is one of lodgepole pine and aspen.

It must be understood that the width of these vegetation zones, as well as their vertical ranges and their composition, vary considerably over the state. Furthermore, the lines of demarcation are seldom sharp and abrupt, but the change from one zone to another is gradual and, over a considerable area, there is a mingling of the typical plants of each zone.

Throughout the state, the pinyon pine-juniper and chaparral associations are usually intermediate between grassland or sagebrush and the timbered slopes. Yellow pine is always a tree of

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lower altitudes than lodgepole pine, while lodgepole pine flourishes at lower elevations than Engelmann spruce and balsam fir. Douglas fir is an associate of both yellow pine and lodgepole pine, but usually does not extend far into the lodgepole pine belt. Aspen, although found from 5,000 feet to timber-line, is best developed in the lodgepole pine zone. White fir has about the same altitudinal limits as lodgepole pine.

GRASS-STEPPE

Distribution.—Grass-steppe or a short-grass formation is the dominating vegetation over the Great Plains of Colorado, from its eastern border up to the foothill base, where it meets a woody type of vegetation, which may be thicket or coniferous forest. It is almost uninterrupted, except by fringes of broadleaf forests along the watercourses, and by fragments of the prairie-grass type of vegetation in its eastern portion, represented by bunch-grasses, and that vegetation peculiar to sand-hills and blowouts. The short-grass type of vegetation, so well exemplified on the plains of Colorado, extends from almost the Canadian line to southern Texas, and eastward to the prairies (tall-grass formation) in the central part of the Dakotas, Nebraska and Texas.

Character of Vegetation.—The two most characteristic grasses of the Great Plains are buffalo-grass (*Buchloe dactyloides*), and grama-grass (*Bouteloua oligostachya*), shallow-rooted plants, indicating a soil with considerable run-off and little penetration. However, there are localities, more or less limited, over which these two grasses may appear relatively unimportant, and taller forms hold sway. For example, near the mountains, especially on a course, non-agricultural soil, which permits a deeper penetration of water, bushy snakeweed (*Gutierrezia sarothrae*) and common, small silvery sage (*Artemisia frigida*) are locally important. Again, in eastern Colorado, adjacent to sand-hills, wire-grass (*Aristida longiseta*) may cover wide stretches. Moreover, taller herbaceous plants may seem to dominate during certain seasons. But, take it the Great Plains over, the distinctive vegetation is a short-grass formation in which buffalo-grass and grama-grass are the most important components.

Climate.—Grass-steppe is a vegetative response to a low, infrequent rainfall, the greater percentage (approximately 75%) of which comes during the growing season, and about 60% of which is during the four months June, July, August and September. Grass-steppe in Colorado occupies territory with a mean annual precipitation ranging from 10 to 20 inches. There is seldom more than 50 inches of snow. The average for 13 stations is 26.6 inches.

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At no period does the snow lie on the ground for any length of time.

TABLE XIV.—PRECIPITATION IN SHORT-GRASS FORMATION (GREAT PLAINS).

Station	Altitude	County	Mean Annual	Total from Oct. to May (inc.)	% from Oct. to May (inc.)	% from June to Sept. (inc.)	Mean Annual Snowfall
Akron	4650	Washington	22.11	....	.....	.....	32.7
Arriba	5248	Lincoln	16.22	6.27	38.65	61.35	24.9
Blaine	3935	Baca	14.02	....	.....	.....	22.9
Burlington	4160	Kit Carson	19.90	8.19	41.16	58.84	18.5
Cheyenne Wells	4279	Cheyenne	17.70	4.45	25.15	74.85	25.1
Cope	4250	Washington	19.90	....	.....	.....	40.7
Ft. Collins	4985	Larimer	15.64	4.62	29.54	70.46	43.5
Grover	5076	Weld	14.37	7.08	49.26	50.74	14.0
Holly	3380	Prowers	13.66	6.48	47.44	52.56	13.0
Las Animas	3899	Bent	13.13	5.95	45.32	54.68	24.0
Pueblo	4734	Pueblo	12.09	5.37	44.33	55.67	23.0
Wray	3512	Yuma	18.88	5.46	28.98	71.02	32.7
Yuma	4138	Yuma	19.13	8.46	48.97	51.03	34.0
		Average	16.67	5.83	39.89	60.11	26.6

The distribution of the precipitation throughout the year in grass-steppe territory is shown in Fig. 10, where it may be compared with that in the sagebrush type of country. Droughts fre-

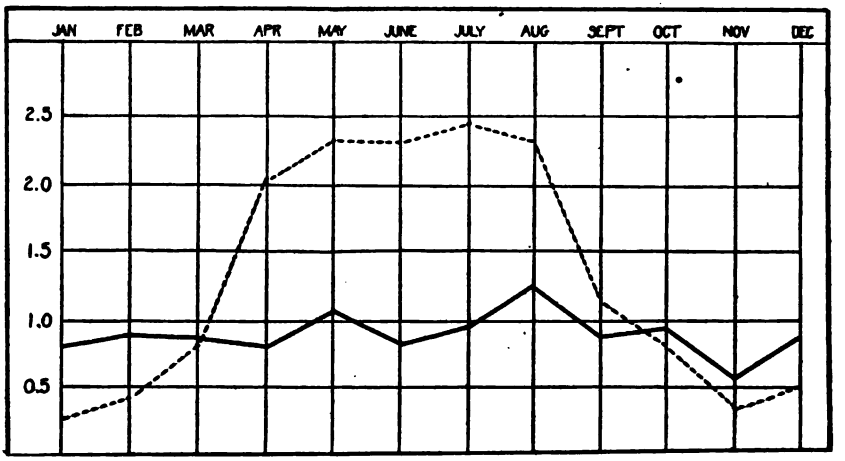

Fig. 10.—Two chief types of rainfall in Colorado. The dotted line shows the grass-steppe (Great Plains) type of rainfall, and the solid line the sagebrush type of rainfall. The first curve, showing monthly precipitation, is an average of 13 grass-steppe stations. The solid-line curve, showing the monthly precipitation in the sagebrush plant community, is an average of 11 stations.

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quently come in late summer. There is a strip along the eastern border of the Great Plains with an annual precipitation approaching 20 inches, an amount slightly higher than for the Plains as a whole, and it is within this strip that we find elements of the prairie-grass formation of the states to the east, and here too "dry-farming" is carried on with slightly more advantage than in the western part of the grass-steppe area. The Plains experience marked variations from the average precipitation (see Fig. 9), that is, there may be very wet years and very dry ones, or a series of these.

The average temperature for the year over the Great Plains is mostly above 50°, the range being from 45° to 56°. Its western limit is approximately the 45° isotherm. However, the factor heat is not the critical one in determining grass-steppe. Water outweighs it in influence. A limited area of grass-steppe in South Park exists under a mean temperature for the year of about 35° to 40°. The summer mean temperature of the Great Plains ranges from 65° to 75°, by far the greater portion being above 70°. The highest temperatures come in July and August. The daily ranges are high, which means warm days and cool nights. The average length of the frostless season is from 125 to 150 days in the northern two-thirds of the Great Plains of Colorado, and on the high land running east of Trinidad, and from 150 to 163 days throughout the Arkansas Valley. There is considerable variation in the length of the frostless season from year to year, (see Fig. 6). The average date of the last spring frost is from May 10 to May 30, although many stations have had frosts as late as May 25 to 30, and some few as late as June 15 to 25. The average date of the first fall frost ranges from August 29 to October 20. As a rule, the first frosts in the fall come near the first part of October.

The relative humidity is generally low, in the neighborhood of 50% to 55%. This low relative humidity, associated with a high percentage of cloudless days, high temperatures, and considerable wind movement, causes a heavy evaporation from the soil surface. Here, again, is a climatic condition with which the dry farmer has to contend. The rate of evaporation is somewhat more rapid in the southern part of the Great Plains than in the northern, hence 15 inches of rainfall in northern Colorado is worth more in crop production than the same amount in the southern localities at the same elevation, and with similar soil conditions.

The percentage of possible sunshine is 65 or above.

Relation to Agriculture.—The grass-steppe of Colorado is a type of vegetation indicative of a low rainfall. Within its area,

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crops are grown with success only under irrigation or under "dry-farming" methods. These methods of dry-farming are concerned with the conservation in the soil of the natural rainfall, that is the prevention of the run-off, which is normally rapid, and of evaporation. The rather pronounced variations in the annual precipitation from year to year make dry-land farming a decided success some years, and as decided a failure other years. Grass-steppe is a region of summer rainfall (see Fig. 10), and dry falls and winters. Hence the germination and growth of summer annuals is favored, while winter annuals frequently find the falls and winters too dry for their development. Fall-sown wheat is liable to have insufficient moisture to bring about germination, and it may suffer from drying out or blowing out during the winter. However, in spite of these difficulties, fall-sown wheat usually is a more satisfactory crop on dry land than spring-sown wheat. Spring wheat suffers from the late summer period of low rainfall, all the more, as this period is accompanied by a high evaporation. A method quite in harmony with the seasonal distribution of the rainfall on the Great Plains is one in which summer tillage is adopted to conserve the rainfall, and is followed by fall-sown grain. This plan enables the cereals to survive the dry fall and winter, by calling upon the stored soil moisture, and the following season finds them well toward maturity before the dry summer months.

Grass-steppe of the Plains is indicative of temperature conditions favorable to a varied agriculture. Corn, sorghum, millet, and the common small cereals are brought to maturity in any portion of its area. The same is true of apples, sour cherries, plums, and small fruits, which are grown with the greatest success in the Arkansas Valley as far up as Canon City, and adjacent to the foothills from Denver northward. There are, however, local districts within these large areas that are not adapted to commercial fruit-growing. Examination of Figs 2, 5 and 7, shows that these areas have an average frostless season of 150 days and over, that the average date of the last spring frost is about May 10, and that the mean temperature for the summer months is close to 70°. Peaches in Colorado are not a safe commercial crop in areas with an average frostless season of less than 150 days, where the average date of the last spring frost is later than May 1 to 10, and where the mean temperature for the summer months (June, July and August) is less than 65°. However, average length of frostless season, average date of last spring frost, and mean temperature for the summer months are not sufficient temperature data upon which to base a conclusion regarding the desirability of an area for the

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growth of a crop. A very important consideration, particularly as regards the fruits, is the character of the winters and springs. Are the winters open and windy? Are there series of early warm days which induce the swelling of buds, and which may be followed by freezing weather? Or does the spring open gradually? The failure of a tender crop, like peaches, on the Plains, even in those sections with a long growing season, and an early date for the last spring frost, and warm summer months, is largely due to the dry, windy winters, and to the inconstancy and fluctuations of the spring weather. Melons find conditions for their growth and maturity most favorable in the southern part of the Great Plains steppe, where the growing season is close to 150 days, and where the average date of the first frost in the autumn is not earlier than October 1. Great Plains localities with frosts coming as early as the middle of September, are unsafe for melon growing as the fruit is usually caught, under such circumstances, about two weeks before maturity.

The establishment of trees under dry land conditions in grass-steppe territory is a difficult, although not impossible, undertaking. The open winters, with their high rate of evaporation, droughts in July and August, the frequent low temperatures, and great diurnal ranges, are difficult hazards for the young tree. However, once established, many of the more drought-resistant trees do well over the Great Plains, even on dry land.

The absence of a snow cover during most of the winter season, accompanied by a cold soil, a dry atmosphere, and a clear sky, is a condition which makes winter-killing from drying out a menace to the fruit-grower, the owner of forest tree plantations, and to the alfalfa-grower. The tenderer cane fruits are regularly buried, and strawberries mulched.

SHRUB-STEPPE

Distribution and Vegetation.—A large part, close to 25 per cent, of Colorado, is covered with a shrub type of vegetation. The principal species composing this shrub-land are sagebrush (*Artemisia tridentata*), greasewood (*Sarcobatus vermiculatus*), shadscale or saltbush (*Atriplex confertifolia*), orache or grey saltbush (*Atriplex canescens*), salt sage (*Atriplex nuttalli*), kochia (*Kochia vestita*), and rabbitbrush (*Chrysothamnus* species). The most important and by far the most extensive shrub-steppe in Colorado is sagebrush. It is the characteristic type of vegetation of the arid districts of western Colorado; this region represents the eastern limit of the sagebrush formation which dominates the

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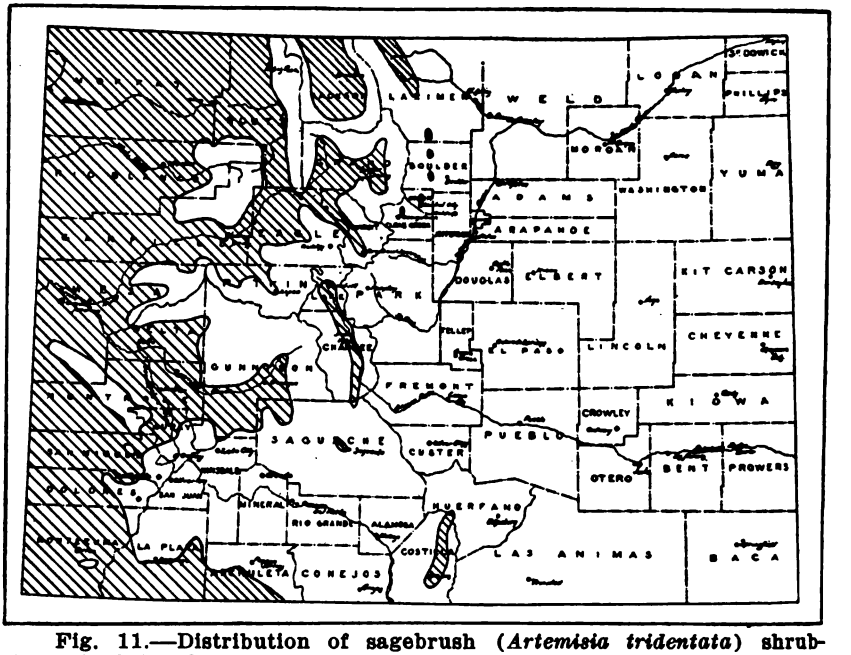

Fig. 11.—Distribution of sagebrush (*Artemisia tridentata*) shrub-steppe in Colorado.

whole Great Basin area. Fig. 11 gives the general distribution of sagebrush in Colorado. It is seen to occupy much of western Colorado, North Park and Middle Park. In narrow valleys, it is on the narrow benches bordering the streams (Fig. 12). It may also clothe rounded hills to their summit. The most typical sagebrush territory in Colorado is in the northwest counties. It grows to an altitude of 10,000 feet in some localities, but as a plant formation it reaches its best development below 9,000 feet. Competition, not temperature, seems to be the limiting factor in its upper altitudinal distribution. Where precipitation and topographic conditions are such as to permit the growth of trees, sagebrush is at a disadvantage. In North Park and Middle Park sagebrush and lodgepole pine forest meet, and the boundary line is sharp. Again, it may form a sharp boundary line with the yellow pine, or aspen, or oak brush, or pinyon pine and juniper. But, in nearly all of these cases, factors other than temperature are determinative.

Types of shrub-steppe that are second in importance only to sagebrush are the greasewood and rabbitbrush associations, which cover the larger part of San Luis Valley, and more limited areas in other sections of the state. Greasewood is present throughout

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Fig. 12.—Near Basalt, Colorado, on Roaring Fork River. The sagebrush slopes, at the base of the mountain, have been cleared, and are now growing excellent crops of small grain, alfalfa and potatoes. Narrow-leaf cottonwood (*Populus augustifolia*) along the stream; oak, aspen and Douglas fir on the steep slopes.

the western section of the state, chiefly at elevations below 7,000 feet.

Shrub-steppe is scattered throughout the entire intermountain area. It occurs in some parts of South Park, and in the Wet Mountain Valley. Locally, it is also found in small patches on the eastern mountain front, and even here and there on the Great Plains. The round-leaved saltbush (*Atriplex confertifolia*), sometimes along with greasewood (*Sarcobatus vermiculatus*) and common Grayia (*Grayia spinosa*), is found chiefly on alkaline flats in western Colorado, especially in the lower valleys. Extensive and typical areas of this association are found in the lower Snake River Valley. The soil it occupies is usually fine-grained, the surface layers dry, and the soil below the first and second foot quite high in salt content. Salt sage or small salt-brush (*Atriplex nuttalli*) is another plant of alkaline flats. Cary* reports it as being the "most conspicuous shrub in Midland Basin, western Routt (Moffat) County; on the desert north of Mack; and on the alkaline stretch of country between Hotchkiss and the West Elk Mountains."

*Cary, M. A biological survey of Colorado, U. S. Dept. of Agri. North Amer. Fauna. No. 33. 1911.

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The Sagebrush (Artemisia tridentata) Steppe.—This is the most important plant community of the shrub type occurring in the state. The name "sage plains" aptly describes this plant community as it appears in many sections. This applies to a uniform and uninterrupted growth over scores of square miles. When viewed from a distance, the sagebrush plant itself seems to be the only plant present. Closer examination shows a few associated shrubby and half-shrubby plants, and a considerable number of herbs. But even at the height of their flowering time, these herbs rarely modify the aspect of the community. There is considerable space between the individual sagebrush plants, and for most of the year, especially after the middle of July, the soil is quite bare. The average height of sagebrush is about 3½ feet. In shallow soil, underlaid by hardpan or rock, or in habitats with an alkaline subsoil, the plants are much smaller, while along streams in deep soil which is easily penetrated by water the plants may be 6 or 7 feet tall.

An extremely prevalent condition in western Colorado is an admixture of sagebrush and pinyon pine-juniper (Fig. 13). One may travel for miles now through sagebrush, now pinyon pine-juniper, the two communities alternating frequently. The transition from one to the other may be abrupt. It is quite obvious that both live under similar climatic conditions, as is evinced by their frequent alternation, and by the growth of sagebrush between the individual pinyon pine and juniper trees, but typical pinyon pine-juniper indicates a rocky soil. "Sage plain" may be interrupted by

Fig. 13.—Alternation of sagebrush and pinyon pine-juniper in western Dolores County. Pinyon pine-juniper occupies a shallow or stony soil, while sagebrush is on a deep, rather fine-grained soil.

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fringes of pinyon pine-juniper on stony outcrops, or where the soil is shallow and underlaid by rock.

Sagebrush seldom occupies a habitat where soil moisture is near the surface. Furthermore, typical sagebrush soil is well-drained, low in water content, and always practically free of "alkali."

The behavior of the native herbaceous plants in the sagebrush steppe suggests what will be the behavior of cultivated herbs under similar conditions. The surface soil, upon which herbs are dependent for their water, becomes exhausted of water in early summer, and the native herbs mature quickly before complete exhaustion takes place. From the middle of July on through the rest of the growing season there is little available water in the soil for shallow-rooted plants.

Climate of Sagebrush Steppe.—The mean annual precipitation on Colorado sagebrush areas ranges from under 10 inches to 17 or 18 inches. The community is most typical, however, in those sections with less than 15 inches of precipitation. The average amount of 11 stations is 13.1 inches. (See Table 15). Shallow-rooted short grasses, such as dominate the Great Plains, could not flourish in a habitat with rainfall distributed throughout the year as it is in shrub-steppe. In fact, the distribution of the rainfall throughout the year is one of the most important climatic differences between these two formations of plants. The precipitation is quite evenly distributed over the different seasons (Fig. 10). There is a winter snowfall. Moreover, snows of the Western Slope lie on the ground for longer periods than they do on the

TABLE XV.—PRECIPITATION IN SAGEBRUSH SHRUB-STEPPE.

Station	Altitude	County	Mean Annual	Total from Oct. to May (inc.)	% from Oct. to May (inc.)	% from June to Sept. (inc.)	Mean Annual Snowfall
Delta	4965	Delta	8.38	4.96	58.95	41.05	14.0
Glenwood Springs	5823	Garfield	12.12	8.11	66.91	34.09	53.0
Grand Junction	4602	Mesa	8.36	5.42	65.09	34.91	17.0
Gunnison	7670	Gunnison	11.09	5.65	50.94	49.06	49.0
Kremmling	7337	Grand	16.79	10.22	61.00	60.90	11.0
Lay	6190	Routt	12.68	8.96	70.66	29.34	67.2
Montrose	5811	Montrose	9.91	5.94	59.94	40.06	28.0
Rangely	5050	Rio Blanco	12.74	7.67	60.20	39.80	49.0
Redvale	6300	Montrose	15.35	9.22	60.07	39.93	28.3
Sapinero	8125	Gunnison	18.69	12.99	69.50	30.50	12.0
Walden	8050	Jackson	7.94	....	.....	.....	29.7
Average			13.10	7.91	62.33	37.64	32.6

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Plains, and in many parts of sagebrush territory, particularly above 7,000 feet, snow accumulates to considerable depths and remains on the ground for long periods.

Sagebrush, as a dominating plant community, flourishes under a quite wide range of temperature conditions (see Table XVI). The mean annual temperature ranges from about 52° to as low as 37° in the Gunnison area, North Park and Middle Park, and the mean summer from 76° to about 56°. The frostless season is exceedingly variable. At Grand Junction it averages 183 days, while at Walden, in North Park, a typical sagebrush country, freezing temperatures may be expected every month, the average length of the frostless season being 56 days. The absolute annual range of temperature is high (102° to 129°).

All in all, sagebrush grows under a wide range of environmental conditions.

Agriculture in the Sagebrush Shrub-Steppe.—Some of the best general farming and orchard lands of Colorado are sagebrush land. Typical sagebrush soil is well-drained, usually deep, and always practically free of "alkali." Sagebrush is not a reliable indicator of temperature conditions, for it is equally well-developed in the lower valleys of the west which have a frostless season suitable to the growth of peaches, sweet cherries, and other tender crops, and in North Park at an altitude of 8,000 feet, where the frostless season is less than 75 days, where the date of the last spring frost is seldom earlier than June 15, and where in many years freezing temperatures are experienced every month. However, from observation throughout Colorado, and judging from the crops grown on sagebrush land at its upper altitudinal limit, it may be concluded that wherever sagebrush forms an extensive and dominating growth, temperature conditions are such as not to make impossible, except in unusual years, the maturing of timothy, alsike, oats, wheat, barley and rye, alfalfa, potatoes, Canadian field peas, strawberries, raspberries, currants, gooseberries, and all of the hardy vegetables. It is not to be assumed, however, that the mere presence of the sagebrush species, or the occurrence of small patches at high altitudes, indicates temperature conditions in the surrounding country favorable to these crops.

In the greater part of the sagebrush area there is a considerable amount of snow, and a snow cover during long periods. This condition favors the wintering over of low perennials, such as alfalfa and strawberries. Furthermore, the stored moisture of winter precipitation is often sufficient to carry spring-sown annuals far into July. Dry land agriculture of the sagebrush country of

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TABLE XVI.—TEMPERATURE IN THE SAGEBRUSH SHRUB-STEPPE.

Station	Altitude	County	Mean Annual	Mean Winter	Mean Spring	Mean Summer	Mean Fall	Average Length Frostless Season	Aver. Date Last Spring Frost	Aver. Date First Fall Frost	Absolute Annual Range
Delta	4965	Delta	49.8	26.7	50.4	72.3	50.0	138	May 11	Sept. 27	114
Glenwood Springs	5823	Garfield	44.3	24.4	46.2	64.5	46.6	112	May 22	Sept. 18	110
Grand Junction	4602	Mesa	52.3	28.0	52.8	76.0	53.3	181	Apr. 18	Oct. 19	106
Gunnison	7670	Gunnison	37.3	9.8	38.1	58.9	40.2	63	June 28	Sept. 1	121
Hot Sulphur Springs	7600	Grand	38.2	....	....	65.6	....	...	.....	.....	117
Kremmling	7337	Grand	37.4	14.5	47.8	64.9	39.1	83	June 12	Sept. 2	128
Lay	6190	Routt	44.7	18.9	41.1	63.6	43.6	85	June 11	Sept. 5	124
Paonia	5694	Delta	49.4	28.1	48.2	69.7	51.0	161	Apr. 30	Oct. 16	102
Rangely	5050	Rio Blanco	44.5	17.5	45.1	65.6	45.4	115	May 16	Aug. 21	129
Sapinero	8125	Gunnison	37.5	16.2	31.4	56.7	40.3	91	June 17	Sept. 15	103
Spicer	8700	Jackson	37.1	18.5	....	....	....	61	June 27	Aug. 27	...
Walden	8050	Jackson	37.6	17.0	36.0	58.4	40.4	56	July 6	Aug. 31	119
Average			42.6	20.0	43.7	65.1	44.9	104	June 1	Sept. 14	116

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western Dolores and Montezuma Counties is largely dependent upon the stored moisture of winter snowfall.

Greasewood Shrub-Steppe (Fig. 14).—This type of vegetation is widely distributed throughout the state, both east and west of the Continental Divide. It is not indicative of any particular set of climatic factors, but is called forth by local soil conditions. Greasewood is almost always an indicator of a high water-table, and consequently of a soil quite rich in "alkali."

The most extensive stretch of greasewood in Colorado is that in the San Luis Valley, where there is an annual rainfall of less than 10 inches. Throughout some parts of this area, the level of ground water is kept high and within the reach of the roots of the shrubs by natural seepage conditions in the Valley. San Luis Valley is a natural basin, with drainage from the mountains on three sides, and although the surface layers of soil are kept dry by excessive evaporation, both summer and winter, and by the scarcity

Fig. 14.—Typical growth of greasewood (*Sarcobatus vermiculatus*)

of rainfall, the subsoil often has a high water content. The level of the water-table has been elevated by the system of subirrigation long practiced in the Valley, and conditions have been made very favorable for the development of a greasewood type of vegetation. In fact, this type of vegetation has widened its limits in the Valley, encroaching upon the rabbitbrush and sagebrush types of vegetation. So-called "seeped" land in the San Luis Valley invariably runs to an almost pure stand of greasewood within twenty to twenty-five years.

Although, as has been said, the presence of a greasewood type of vegetation is not a dependable index of climatic factors, herewith follows a table giving temperature relations of the very extensive shrub-steppe of the San Luis Valley. From this table it is seen that the mean summer temperature (60.9°) is suitable for the maturing of the small cereals, except millets and sorghums, of po-

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tatoes, alfalfa, Canada field peas, and some of the hardiest fruits and vegetables. The tenderer fruits and melons are not a success, as might be judged from the mean summer temperature, the short frostless season (average, 103 days) and the average date of the last spring frost (June 11).

TABLE XVII.—TEMPERATURE, SAN LUIS VALLEY.

Station	Altitude	Mean Annual Temperature	Mean Winter Temperature	Mean Spring Temperature	Mean Summer Temperature	Mean Fall Temperature	Aver. Length Frostless Season	Aver. Date Last Spring Frost	Aver. Date First Fall Frost	Absolute Annual Range
Blanca	7865	42.6	23.4	....	....	....	103	June 11	Sept. 21	108
Garnett	7576	40.5	18.8	41.3	60.6	41.2	95	June 6	Sept. 12	115
Manassa	7700	42.4	22.7	41.7	60.6	43.4	90	June 4	Sept. 9	101
Saguache	7740	43.5	22.0	43.5	62.3	45.2	124	May 26	Sept. 25	112
San Luis	7794	42.6	22.7	42.2	60.2	44.8	106	July 5	Sept. 20	111
Average.....	....	42.3	23.9	42.2	60.9	43.7	103	June 11	Sept. 18	109

CHAPARRAL OR BRUSHLAND

Chaparral is a dense growth of shrubs. It is synonymous with thicket. Chaparral in Colorado is mainly of scrub oak (*Quercus spp.*), or buckbrush (*Symphoricarpos spp.*), or mountain mahogony (*Cercocarpus parvifolius*), or Juneberry (*Amelanchier*), or "canyon thicket" composed of chokecherry (*Prunus melanocarpa*), thornapples (*Crataegus spp.*), and others.

Scrub oak forms the most extensive thicket growth in the State. It is absent from the northeastern part of the State, from North Park, Middle Park, and South Park. Its northernmost limit along the eastern front range is somewhere between Palmer Lake and Denver. It is sometimes an alternating association with pinyon pine-juniper; again it may form a distinct fringe along the upper edge of the sagebrush association. As a well-defined chaparral, oakbrush is seldom above 8,000 feet. Although it is growing under a wide range of climatic conditions, such as is found between 4,000 and 9,000 feet, its upper altitudinal limit, as a well-formed plant community, is not above the limit of the successful growth of alfalfa, potatoes, small grains, strawberries, hardy cane fruits, and the hardy vegetables.

In western Colorado, oakbrush is commonly associated with buckbrush (*Symphoricarpos spp.*). Both scrub oak and buckbrush usually occupy a soil that is deep, rich, and suitable for agricultural purposes. The hill slopes in Fig. 15 show patches of scrub oak and buckbrush.

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Fig. 15.—Cultivated sagebrush land in vicinity of Steamboat Springs. Alfalfa, potatoes, small grain, timothy and alsike clover are grown.

Mountain mahogany is generally distributed throughout Colorado in the foothills and on the lower mesas. It clothes dry, rocky hill-slopes, indicating arid conditions that are incapable of being utilized agriculturally. Climatically, it belongs to the western yellow pine zone. Skunk-brush (*Rhus trilobata*) is a common associate.

The "canyon thicket", of chokecherry, thornapples, ninebark, etc., is found at the mouths of canyons at low elevations, and is indicative, generally, of a climate intermediate between that of the Great Plains and the yellow pine zone, or between the "sage plains" and the zone above it.

Chokecherry (*Prunus melanocarpa*) forms a chaparral growth in western Colorado, alternating on the slopes with oakbrush, buckbrush, and other shrubs of the yellow pine zone. Its distribution and agricultural relations are similar to those of the scrub oak chaparral.

Common Juneberry (*Amelanchier alnifolia*) makes a dense thicket growth in sections of western Colorado, at elevations much the same as occupied by scrub oak, buckbrush and chokecherry.

PINYON PINE-JUNIPER WOODLAND ZONE

Distribution and Vegetation.— Pinyon pine (*Pinus edulis*) and the one-seeded juniper (*Juniperus monosperma*) form a rather distinct belt of vegetation which occupies a position just below the yellow pine zone. The general distribution of this belt is shown in Fig. 16. It is seen to form a belt along the lower foothills in the section south of Colorado Springs, and running up the

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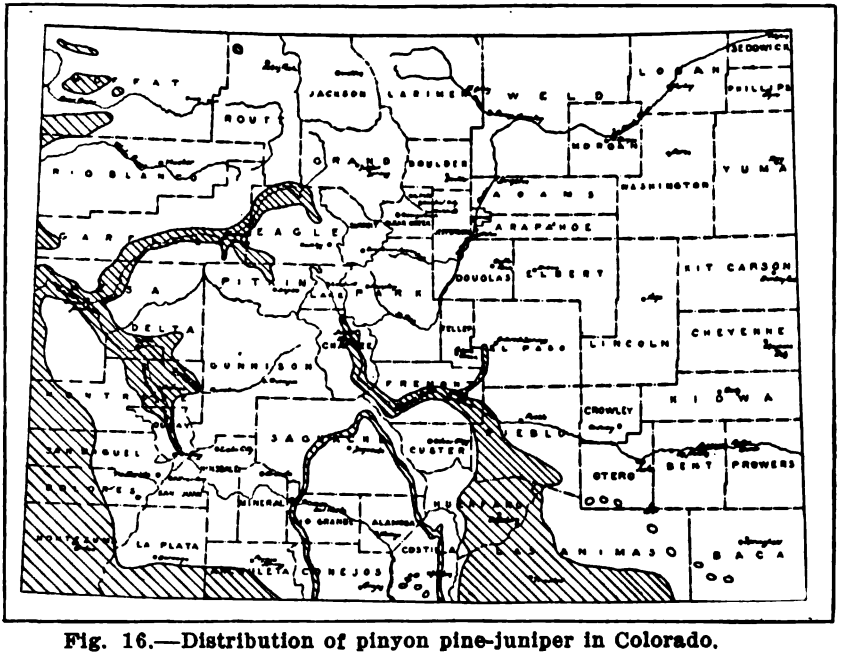

Fig. 16.—Distribution of pinyon pine-juniper in Colorado.

Fig. 17.—Rabbitbrush in San Luis Valley. Mt. Blanca in background. Note the dark strip of pinyon pine-juniper at the base of the mountain, above which are sparsely timbered slopes, and the alpine treeless areas at the crest.

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Arkansas River to above Buena Vista. There is a fringe of pinyon pine-juniper on the warm slopes that overlook San Luis Valley (Fig. 17). The south corner of Archuleta County, the southern part of La Plata County, and most of Montezuma County, have scattering growths of this community. It extends northward, including the western half of Dolores, San Miguel and Montrose Counties. The warm slopes in the Grand and Uncompaghre Valleys, up to McCoy in Eagle County, above Basalt in Pitkin County, and to Ouray in Ouray County, bear stands of pinyon pine-juniper, which may be pure in places, but often mixed with sagebrush. In the northwest counties, there are a few areas of pinyon pine and juniper, particularly along the western border of the State. The pinyon pine-juniper belt is best developed below 7,000 feet, but in the San Luis Valley and many other sections it may reach close to 9,000 feet. When found at high altitudes, it is always on south exposures that become very warm. It does not reach the altitudes that sagebrush does, and its range of temperature conditions is much less than that of sagebrush. However, over thousands of square miles, pinyon pine-juniper and sagebrush alternate (Fig. 13), the former occupying rough, broken country, or shallow, stony soil, while sagebrush occurs on the more level ground, which has a deeper and finer soil. It is not uncommon to see sagebrush land cultivated up to the edge of a rocky knoll, capped with pinyon pine and one-seeded juniper.

Climate, and Relation to Agriculture.—The mean annual precipitation in the pinyon pine-juniper belt is uniformly under 15 inches. The summer temperature in a large percentage of the area is not below 65°, although in some few localities it may be several degrees lower. The average length of the frostless season is usually between 100 and 125 days, and the average date of the last spring frost about May 20. Pinyon pine-juniper is a plant community of warm slopes, and warm soil (Fig. 18). Although often local in its distribution above 6,500 feet, it is a reliable indicator there of a warm habitat, of a warm island, so to speak, in a cool area. The pinyon pine-juniper woodland is a mark of temperature conditions which permit the growth of all but the tenderest fruits, all the small grains, flax, sugar beets, potatoes, alfalfa, and the garden vegetables, excluding melons. In the lower part of the belt, peaches, sweet cherries, melons, and other tender crops yield bountifully. Much valuable orchard land of Colorado is cleared pinyon pine-juniper soil. Scattered pinyons, and less often one-seeded junipers, will be found considerably above the limits of growth for the crops mentioned, but such individual spec-

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imens are growing only in very isolated spots. Care should be exercised in the selection of sites for fruit growing along the upper limits of the pinyon pine-juniper zone.

YELLOW PINE FOREST ZONE

Distribution, and Vegetation.—The yellow pine forest community belongs to the foothills in most sections of Colorado. On the eastern foothills from the Colorado-Wyoming line to the Palmer Lake Divide, yellow pine quite regularly comes in at about 6,000 feet, and extends to 8,000 feet, where it meets the lodgepole

Fig. 18.—Below Ouray; potatoes and grain on sagebrush land. Pinyon pine and juniper on the slopes.

pine forest. Often, its lowermost limit is on the mesas, meeting there the grassland of the Plains. Yellow pine extends eastward on the Arkansas-Platte Divide, 50 miles or more east of Castle Rock. The transition from grass-steppe to yellow pine on the east foothills of southern Colorado is made by pinyon pine and juniper. Yellow pine fringes the San Luis Valley, occurring above

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the pinyon pine-juniper belt. In the southwestern counties the lower altitudinal limit of the forest is about 7,000 to 7,500 feet; at this limit it may be mingled with chaparral of oak, chokecherry, Juneberry, buckbrush, etc. It extends northward to the Gunnison and Grand drainage systems, the growth becoming more scattering as it reaches in that direction. In the northwest counties, in Middle Park and North Park, yellow pine is not an important tree, and seldom forms a forest of any extent.

The principal tree associate of yellow pine is Douglas fir (*Pseudotsuga mucronata*). These two trees will alternate through out the yellow pine belt; Douglas fir dominates the cooler and moister north exposures, while yellow pine more frequently holds to the warmer, and drier exposures. This alternation is most noticeable at lower altitudes. Douglas fir extends to higher altitudes than yellow pine, and is often a strong element in the lodgepole pine belt of the eastern slope.

Other characteristic plants in the yellow pine association are: Chokecherry (*Prunus melanocarpa*), buckbrush (*Symphoricarpos spp.*), skunk-bush (*Rhus trilobata*), sumac (*Rhus glabra*), yellow-flowered currant (*Ribes longiflorum*), red currant (*Ribes cereum*), New Jersey tea (*Ceanothus fendleri, C. pubescens*), wax flower (*Edwinia americana*), Rocky Mountain maple (*Acer glabrum*), *Kunzia tridentata*, Juneberry (*Amelanchier*), squaw apple (*Peraphyllum ramossissimum*), narrow-leaved cottonwood (*Populus angustifolia*), alder (*Alnus tenuifolia*), stream-side birch (*Betula fontinalis*), Oregon grape (*Berberis repens*), bearberry (*Arctostaphylos uva-ursi*) and spiraea (*Holodiscus dumosus*). The quaking aspen is abundant in the yellow pine belt, but it finds a more suitable environment above it.

The yellow pine forest goes to higher elevations on south exposures than on north exposures, and long tongues of vegetation more properly belonging to the lodgepole pine belt, or its altitudinal equivalent, penetrate it along cool mountain streams and on north exposures.

Climate.—The yellow pine forest seldom displays its typical development in those regions possessing less than 15 inches of precipitation annually. In northern Colorado, the 15-inch precipitation line (see Fig. 8), is practically co-extensive with the lower limit of the yellow pine zone, while in the southern part of the state the 20-inch line quite closely follows the lower limit of the belt. The snowfall exceeds that of the grass-steppe, sagebrush

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and pinyon pine-juniper communities by a large amount. The mean annual temperature ranges from 40° to 47°, while that for the summer months is never below 60°. The frostless season is very rarely below 75 days, the usual length being from 85 to 125 days. The average date of the last spring frost is usually between May 20 and June 1, although in the southwestern counties, it may frequently come as late as the middle of June.

TABLE XVIII.—PRECIPITATION IN YELLOW PINE FOREST ZONE.

Station	Altitude	County	Mean Annual	Total from Oct. to May (inc.)	% from Oct. to May (inc.)	% from June to Sept. (inc.)	Mean Annual Snowfall
Castle Rock	6220	Castle Rock	19.40	12.80	64.33	35.67	62.8
Fremont Exp. Sta.	8850	El Paso	18.08	.....	.....	.....	90.7
Ft. Lewis	7610	La Plata	19.46	.....	.....	.....	....
Georgetown	8550	Clear Creek	15.62	7.87	50.39	49.61	93.6
Gold Hill	7200	Boulder	20.19	10.23	50.67	49.33	....
Husted	6596	El Paso	14.79	.....	.....	.....	51.0
Idaho Springs	7543	Clear Creek	15.74	8.89	50.52	49.48	67.0
Monument	7200	El Paso	24.36	8.25	33.46	66.54	82.0
Pagosa Springs	7108	Archuleta	21.15	11.08	52.39	47.61	84.0
Tacoma	7300	La Plata	21.57	16.37	75.94	24.06	87.0
Average			19.04	10.70	53.95	46.05	77.4

Relation to Agriculture.—The yellow pine forest community forms a vegetative belt in our mountains varying in width, and with an altitudinal range of approximately 6,000-8,000 feet in northern Colorado, and 7,000-9,000 feet in the southern sections. Throughout much of this area, the slopes are too steep to cultivate, or the soil is stony and shallow; moreover, many cultivated areas are as yet inaccessable, except to the stockman. In fact, a very large percentage of the area is economically adapted only to grazing and timber growing.

The presence of the yellow pine forest is quite a reliable index of temperature conditions favorable to the maturing, most seasons, of wheat, oats, barley and rye. Oats and barley are the two most common small cereals of this belt, and in seasons that are considerably below the average in length, are cut for forage. Potatoes

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TABLE XIX.—TEMPERATURE, YELLOW PINE FOREST ZONE.

Station	Altitude	Mean Annual Temperature	Mean Winter Temperature	Mean Spring Temperature	Mean Summer Temperature	Mean Fall Temperature	Aver. Length Frostless Season	Aver. Date of Last Spring Frost	Aver Date of First Fall Frost	Absolute Annual Range	Mean July Temperature
Castle Rock	6220	46.5	27.6	44.7	65.6	47.6	132	May 14	Sept. 21	116	67.5
Fremont Exp. Station	8850	40.7	....	....	....	....	83	June 18	Sept. 9	103	55.7
Georgetown	8550	42.2	29.2	40.6	60.2	43.9	...	.....	.....	101	62.1
Gold Hill	7200	45.1	....	31.8	62.1	....	...	May 17	Oct. 3	...	63.9
Husted	6596	46.2	29.1	44.9	65.4	48.2	...	.....	.....	116	67.5
Idaho Springs	7543	44.8	28.5	41.4	61.2	45.3	132	May 20	Sept. 27	99	62.8
Monument	7200	42.2	24.6	40.1	60.5	45.7	106	June 3	Sept. 17	102	61.1
Pagosa Springs	7108	41.2	19.2	40.3	60.1	43.9	78	June 28	Sept. 12	119	62.1
Tacoma	7300	42.1	....	....	....	....	125	May 15	Sept. 17	90	....
Average		43.4	26.4	40.9	62.2	45.8	109	June 1	Sept. 19	106	62.8

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Fig. 19.—On the South Fork of the South Platte River, altitude about 8,000 feet. Hill slopes clothed with typical yellow pine. Alfalfa and small grain in the cultivated area.

and alfalfa (Figs. 19 and 20) are both well-suited to the yellow pine zone. Smith* has shown that the potato makes its best development in those sections of the country where the mean annual temperature is between 40° and 50°, and where the mean for July is not over 70°. Reference to the climatic data for the yellow pine forest community shows a range of the mean annual temperature from 40° to 47°, and the mean for July 62° to 67°. The hardier cane fruits and strawberries are usually a success, except in the higher parts of the zone. All of the hardier vegetables, such as onion, carrot, parsnip, parsley, beet, radish, lettuce, turnip, cabbage, rutabaga, rhubarb, mangel-wurzel, pea, and early sugar corn, do well. Tomatoes, cucumbers, peppers, beans, and other tender vegetables are grown with success only during the most favorable seasons, or in the lower part of the zone.

LODGEPOLE PINE FOREST ZONE

Distribution and Vegetation.—Lodgepole pine (*Pinus murrayana*) is bounded on its lower edge by the yellow pine forest and on its upper by the Engelmann spruce-balsam fir forest. Its usual altitudinal range is from 8,000 to 10,000 feet. However, its verti-

*The Effect of Weather Upon the Yield of Potatoes, Monthly Weather Review Vol. 43, No. 5, pp. 222-236, 1915.

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Fig. 20.—Above Pagosa Springs. Yellow pines dominate the surrounding hills; scattered yellow pines in a field of timothy. Alfalfa, small grain and potatoes grown in vicinity.

cal distribution varies considerably; sometimes it goes as low as 7,500, and as high as 11,000 feet.

The chief tree-associates of lodgepole pine are the aspen (*Populus tremuloides*), Douglas fir at its lower limit, and Engelmann spruce at its upper limit. The narrow-leaf cottonwood does not penetrate the zone; it is climatically restricted to the yellow pine belt. The chief shrubs of the lodgepole pine zone are blueberries (*Vaccinium erythrococcum, and V. oreophilum*), bear berry (*Arctostaphylos uva-ursi*), American twin flower (*Linnaea americana*), shrubby cinquefoil (*Dasiphora fruticosa*), elder (*Sambucus microbotrys*), honeysuckle (*Lonicera involucrata*) and Canadian buffalo-berry (*Lepargyrea canadensis*). Some of the most common herbs are anemone or pasque flower (*Pulsatilla hirsutissima*), candy tuft (*Thlaspi coloradense*), buckbean (*Thermopsis divaricarpa*), wall flower (*Erysimum wheeleri*), fireweed (*Chamaenerion angustifolium*), Indian paint brush (*Castilleja spp.*),Arnica (*Arnica cordifolia*), beard tongue (*Pentstemon alpinus, P. procerus*), and erigeron (*Erigeron eximius, E. macranthus*).

Climate, and Relation to Agriculture.—The mean annual temperature in the lodgepole pine belt ranges from about 28° to 40°. The average of 11 stations is 34.9° (see Table XX). In many parts of the state, the 40° isotherm follows quite closely the lower limit

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of the lodgepole pine zone. The isotherm 60° for the summer months is approximately co-extensive with the lower limit of this community, and its upper limit has a summer average of 53.6°. The frostless season is seldom longer than 75 days, and very frequer much shorter.

Except in a few localities, the annual precipitation is a' inches, and in places as high as 25 to 28 inches. Where lo pine and yellow pine grow under equal precipitation amou former will usually occupy exposures that are cooler and

TABLE XX.—TEMPERATURE, LODGEPOLE PINE FOREST ZO

Station	Altitude	Mean Annual Temperature	Mean Winter Temperature	Mean Spring Temperature	Mean Summer Temperature	Mean Fall Temperature	Aver Length of Frostless Season	Aver. Date of Last Spring Frost
Ashcroft	9583	35.7	17.8	33.4	53.4	34.7	61	July
Breckenridge	9524	32.6	16.4	30.9	51.7	36.5	35	.....
Crested Butte	8867	33.1	12.7	....	....	....	...	.....
Cripple Creek	9396	....	....	....	....	....	...	.....
Dillon	8800	33.9	13.4	....	....	....	...	....
Dumont	8000	43.0	....	....	....	....	112	....
Frances	9300	40.3	23.6	37.6	58.5	41.9	110	Ma
Fraser	8671	31.3	12.9	....	....	....	...	..
Fremont Exp. Sta..	8850	40.7	....	....	....	....	83	Ju
Long's Peak (near)	8600	28.2	22.8	53.8	53.4	43.2	62	.
Hermit	9843	31.7	11.8	....	....	....	45	
White Pine	9500	33.3	15.7	31.1	50.9	35.9	32	
Average.....		34.9	18.4	33.4	53.6	38.4		

Lodgepole pine, as a strongly dev
dicates temperature conditions too l
small cereals, for the profitable grow
and any but the most hardy vegetables.
fruits are raised for home use along its
alsike clover are grown now and then. Exc
falfa and potatoes, and small grains are freq
sagebrush strips or oakbrush land that touches
association, but, as a rule, an increase of but 200
vation is sufficient to bring about temperature con
able to these crops. It is at the very upper limit of agricultural possibilities, that the greatest care needs be exercised in the selection of areas for cropping purposes. Just here, exposure counts for the most, and here too, a hundred feet difference in altitude may be the deciding factor in making for a success or a failure in the growth of a crop. A growth of lodgepole pine tells one that he is approaching, or is beyond, the upper altitudinal limit of

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TABLE XXI.—PRECIPITATION, LODGEPOLE PINE FOREST ZONE.

Station	Altitude	County	Mean Annual Precipitation	Mean Annual Snowfall
roft	9483	Pitkin	20.78	148.1
ridge	9524	Summit	24.03	199.4
	8445	Park	13.57	51.8
tte	8867	Gunnison	25.82	157.5
ek	9396	Teller	17.19	83.9
	8800	Summit	13.51	94.0
	8000	Clear Creek	17.56	75.0
Fish Hatchery	8000	Larimer	18.35	102.0
	9300	Boulder	28.66	175.0
riment Station	8850	El Paso	18.08	90.7
	9843	Hinsdale	19.22	12.5
ear)	8600	Larimer	19.83	127.0
	9500	Gunnison	33.30	157.0
			25.53	112.9

Fig. 20.—A bo rounding hills; grain and potatoes

griculture. The area is economically adapted to lum-grazing.

WHITE FIR FOREST ZONE

e fir (*Abies concolor*), plant community belongs to mountains of the State. Here, it takes the place of cat of the northern mountains. Its common altitudinal o 10,000 feet. Its climate is very similar to that of ne association, and it bears the same relation to cal distribution va 7,500, and as high a

SPRUCE-BALSAM FIR FOREST ZONE

The chief tre at an altitude of about 10,000 feet, and (*Populus tremuloides*), mann spruce at its upper li covers all the high mountain ranges and not penetrate the zone; it is pen parkings and streamside meadows pine belt. The chief shrubs o grazing is excellent. On account of its berries (*Vaccinium erythrococ* g of crops is excluded. Some native (*Arctostaphylos uva-ursi*), A The association indicates non-agricul-cana), shrubby cinquefoil microbotrys), honeysuc buffalo-berry (*Lepar* mon herbs are anem ft (*Thlas* V. M. Co

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Bulletin 225 February, 1917

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A COMPARATIVE BACTERIOLOGICAL STUDY OF THE WATER SUPPLY OF THE CITY AND COUNTY OF DENVER, COLORADO

BY

WALTER G. SACKETT

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1917

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Denver's Water Supply---Lake Cheesman, Showing Dam and Water Flowing Over Spillway

A Comparative Bacteriological Study of the Water Supply of the City and County of Denver, Colorado

By WALTER G. SACKETT

There is, perhaps, no city in the United States where an abundant supply of pure, wholesome drinking water is more important to the health of the public at large than Denver, Colorado. This is very apparent to any one who has traveled in the West during the summer time and has observed the thousands of tourists who visit the Capitol City each season. Even with her magnificent climate, cloudless skies, and her other natural advantages, Denver could never have attained to her present enviable position among the cities of the world as a health resort and a most desirable place to live, were it not for her splendid supply of pure, mountain water.

Pure as such a water is believed to be in the popular mind, yet a supply of this character may become the source of much grief from a health standpoint and may prove extremely dangerous to the community unless it is under the constant supervision of experts who watch its chemical and bacteriological character from day to day.

The Denver Union Water Company, a Colorado corporation organized in 1894, which supplies Denver with its water, has recognized the great importance of bacteriological and chemical examinations of the water, as well as the necessity for the accurate control of its filters and sterilizing plants. To this end it maintains a modern chemical and bacteriological laboratory in Denver in charge of Dr. H. I. de Berard. The laboratory is finished thruout in white enamel, has cement floors, and in every respect presents a most pleasing and sanitary appearance. Its equipment, including electrically heated and regulated incubators, sterilizing and distilling apparatus, is of the very latest design.

Daily analyses of the water from each source of supply, as well as from different taps over the city, are made in the Company's laboratory to test the condition before it enters the filters and after it is treated. An accurate check is thus kept on the work done each day by each unit of the system. Any trace of im-

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purity in the raw water is at once discovered and remedied by proper treatment.

In addition to its resident chemist and regular assistants in the laboratory and at the filtration plants, the Company employs as consulting chemists and bacteriologists a number of the best known and most skilled water experts in the country. These experts visit Denver frequently for the purpose of checking the work done by the filter plants and offering suggestions for keeping the purification system fully abreast of the times.

SOURCE OF SUPPLY

The principal source of supply is Lake Cheesman, located fifty miles from Denver, and formed by impounding the waters of the South Fork of the South Platte River and Goose Creek. The surface area of this reservoir is 879 acres, and it has a storage capacity of 26,000,000,000 gallons—enough to supply Denver for two years without replenishment or assistance from any other source. From Cheesman Lake the water is carried down South Platte Canon in the channel of the South Platte River to the intake of the water system, 25 miles below, and 25 miles from Denver. A 60-inch pipeline conveys the water from the intake works to Marston Lake, which can accommodate 6,400,000,000 gallons and to Platte Canon reservoir, with a storage capacity of 300,000,000 gallons.

Besides the Platte River water, Marston Lake receives an additional supply from Bear Creek taken out above Morrison.

Cherry Creek, thru a system of infiltration galleries, contributes a limited amount to the city supply.

FILTRATION AND TREATMENT

Three methods of purification by filtration are employed in connection with the Denver supply:

1. Mechanical filtration is practiced at the Willard plant, which has a daily capacity of 15,000,000 gallons, and at the two Marston Lake plants with a combined daily capacity of 25,000,000 gallons. The filtered water from the Willard plant is subsequently treated with hypochlorite. Chlorine gas and hypochlorite are used at the two Marston Lake plants, respectively.

2. An English slow sand plant located at Platte Canon with six filter beds having a total filtering area of 10½ acres is capable of furnishing 30,000,000 gallons of filtered water daily. Preliminary sedimentation is accomplished in Platte Canon Reservoir. Hypochlorite is added to the filtered water as needed.

3. Infiltration galleries located near the slow sand filter beds and Lehow Lake, along the South Platte River above Mississippi

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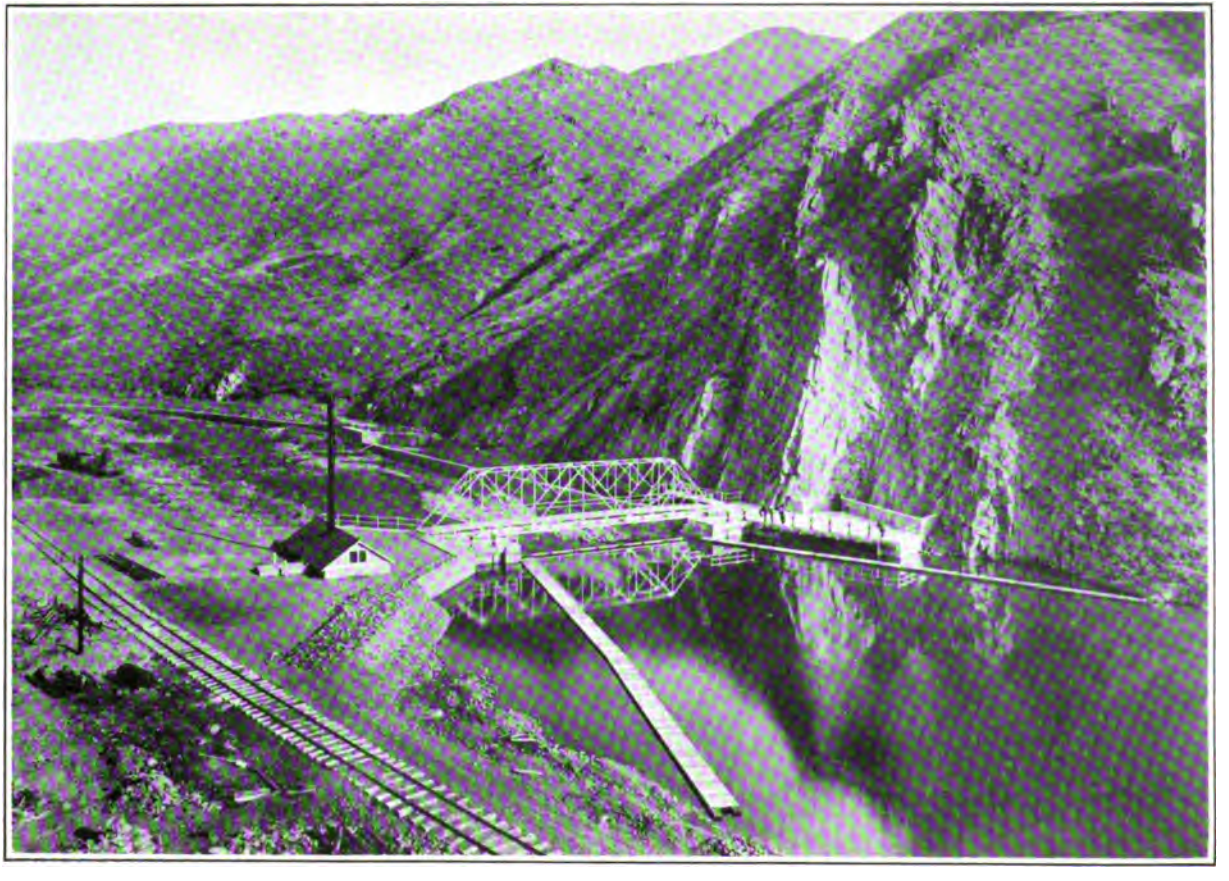

Intake on South Platte River in Platte Canon

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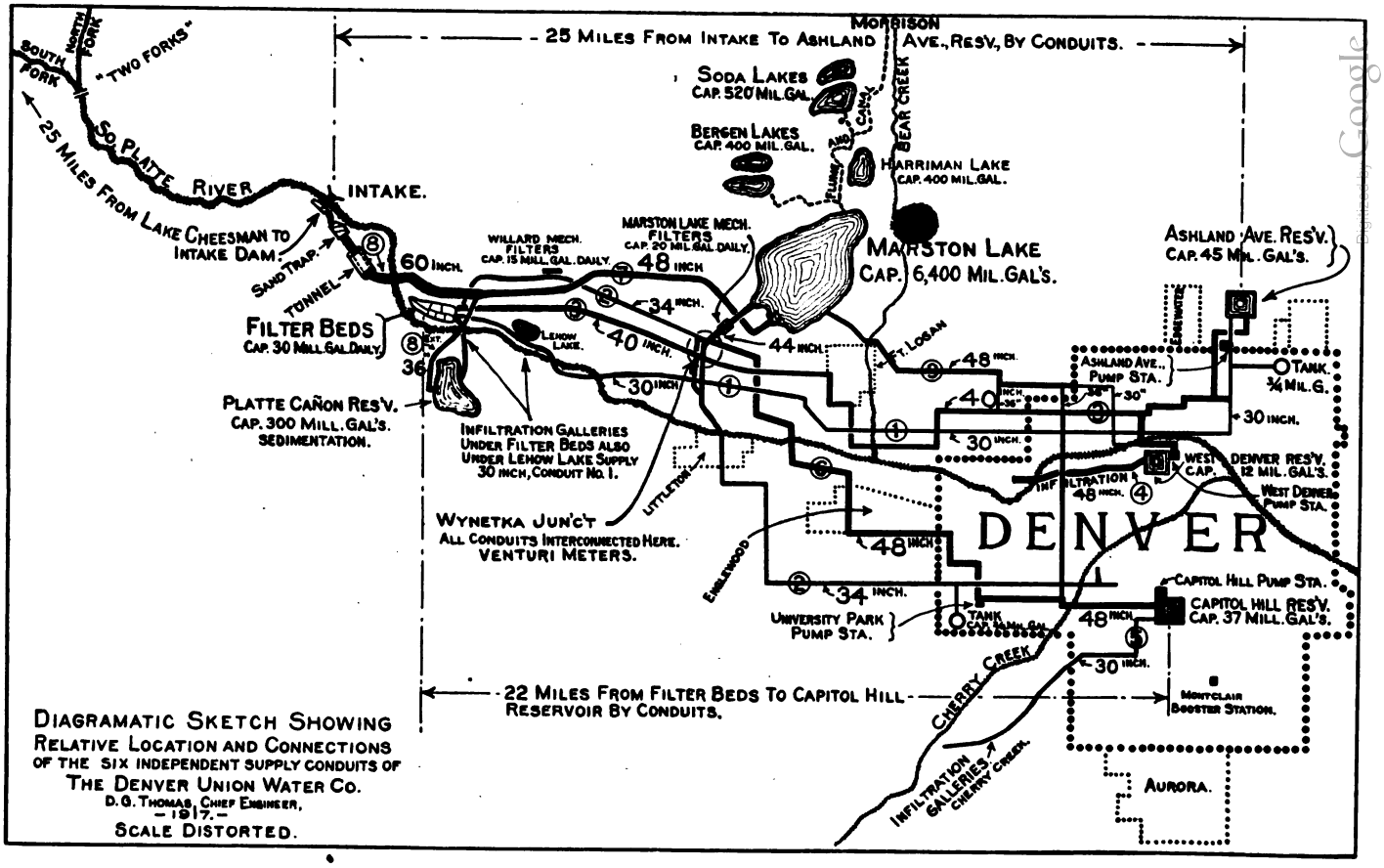

Diagramatic Sketch Showing Relative Location and Connections of the Six Independent Supply Conduits of The Denver Union Water Co.

D. G. Thomas, Chief Engineer, –1917.–

Scale Distorted.

Avenue, and Cherry Creek near Sullivan complete the filtration system.

All of these waters, with the exception of that from Cherry Creek, are treated with either chlorine gas or hypochlorite. The total capacity of the combined plants approximates 81,000,000 gallons of filtered water daily. The population of Denver is, in round numbers, 250,000; the daily water consumption varies from 250 to 350 gallons per capita.

A diagramatic representation of the entire system is shown on page 5.

PATROL OF THE WATER SHED

While the Denver Union Water Company is exercising every precaution to make the water safe for domestic purposes, it does not depend entirely upon the purification plants to accomplish this. It goes without saying that, all things being equal, the purer the raw water the more easily can the impurities be removed and the purer will be the filtered water.

Altho the water-shed in the vicinity of Cheesman Lake is so sparsely settled that it will average little more than one person to the square mile, the Denver Union Water Company recognized the possible danger of pollution from this source, as well as from Platte Canon, and secured the passage of an ordinance which provides for the protection and preservation of the purity of the water supply of the City and County of Denver and for the patrol of the water-shed, and the arrest and punishment of all persons who violate the provisions of the act. The ordinance covering this point follows:—

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View Showing Filter Beds and Subsidence Reservoir at Platte Canon

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BY AUTHORITY
Ordinance No. 102.
Series 1909
Supervisor's Bill No. 32,
Introduced by Sup. Robertson
A BILL FOR

AN ORDINANCE TO PROTECT AND PRESERVE THE PURITY OF THE WATER SUPPLY OF THE CITY AND COUNTY OF DENVER, AND PROVIDING FOR THE PATROL OF THE SOUTH PLATTE RIVER AND BEAR CREEK AND ANY OF THEIR TRIBUTARIES FROM THE FIFTEENTH STREET BRIDGE OVER SAID RIVER IN THE CITY AND COUNTY OF DENVER TO THE HEADWATERS OF SAID STREAMS AND FOR THE ARREST AND PUNISHMENT OF ALL PERSONS VIOLATING THE PROVISIONS OF THIS ORDINANCE.

Be it Enacted by the Council of the City and County of Denver:

Section 1. It shall be unlawful for any person to deposit into the channel of the South Platte river or Bear creek, or any of their tributaries above the Fifteenth street bridge over said river in the City and County of Denver or between or upon the banks of said streams, any unwholesome matter or substance whatever tending to the defilement or pollution of the water of said streams, or to allow the drainage from any sewer, drain or cesspool to drain into or percolate into said streams, or their tributaries, or any of them, or to permit any dead animal or decaying vegetable matter to be placed or left within a distance of three hundred (300) feet of the banks of any said streams, or their tributaries, or to do any other act or thing whereby the water of said streams might become polluted or unfit or unwholesome for human consumption; Provided, That the disturbances of water by placer mining or tailings from ore reduction mills flowing into any of said streams or tributaries shall not be construed as defilement or pollution of the water thereof.

Section 2. The Health Department of the City and County of Denver shall appoint one or more special officer or officers as shall be determined by the Health Department and the Mayor, to be approved by the Mayor, to patrol the South Platte river and Bear creek and their tributaries from the Fifteenth street bridge over said South Platte river in the City and County of Denver to the headwaters of said South Platte river and Bear creek and their tributaries, to enforce the provisions of Section one of this

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ordinance, which officer or officers shall have power to cause the arrest of any person or persons who shall violate the provisions of Section one of this ordinance, or who shall omit, neglect or refuse to obey said officer or officers or shall resist the same, or shall refuse, omit or neglect to obey any special regulations of the said Health Department of Mayor adopted or made to carry out and fulfill provisions of Section one of this ordinance, and to transport the parties so offending to the City and County of Denver to be tried before the Justice of the Peace of the City and County of Denver having exclusive original jurisdiction under the charter of said City and County of all cases arising under the charter and the ordinances of said City and County, and upon a conviction of the said party or parties, shall be fined in a sum not less than twenty-five dollars ($25.00), nor more than two hundred dollars ($200.00), and every omission, neglect or continuance of the thing commanded or prohibited by this ordinance for a period of twenty-four (24) hours shall constitute a separate and distinct offense, and shall be fined accordingly."

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Laboratory of The Denver Union Water Company

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BACTERIOLOGICAL EXAMINATION OF DENVER CITY WATER SUPPLIED BY THE DENVER UNION WATER COMPANY—COMPARATIVE RESULTS FROM FOUR LABORATORIES.

At the request of Mr. D. G. Thomas, Chief Engineer of the Denver Union Water Company, a comparative study of the raw and treated waters furnished by the Company was undertaken November 11, 1916, by four different laboratories working separately and independently. Those co-operating in this investigation were Dr. Wm. C. Mitchell, Bacteriologist for the City and County of Denver, Denver, Colorado, Dr. John B. Ekeley, State Chemist, University of Colorado, Boulder, Colorado, Dr. H. I. de Berard, Chemist, Denver Union Water Company, Denver, Colorado, and Professor W. G. Sackett, Bacteriologist, Colorado Experiment Station, Fort Collins, Colorado.

On November 11th, representatives from the four above laboratories met in Denver and were taken by automobile on an inspection trip over practically the entire system. Each had his own sterilized sample bottles and took samples according to his own particular practice from twelve different points over the system. These included the following:—

1. Mississippi Avenue, infiltration galleries, inlet West Denver reservoir; treated.
2. Platte River, intake to Marston Lake, 48-inch conduit; raw.
3. Bear Creek; intake to Marston Lake, flume; raw.
4. Marston Lake; outlet to North Side Marston Lake plant; raw.
5. North Side Marston Lake plant; treated.
6. Platte Canon infiltration galleries, 30-inch conduit, Wynetka; treated.
7. Slow sand filters, 40-inch conduit, Wynetka; treated.
8. Willard rapid filters, 34-inch conduit, Wynetka; treated.
9. South Side Marston Lake plant, 48-inch conduit, Wynetka; treated.
10. Drinking fountain, City, First and Broadway.
11. Cherry Creek infiltration galleries, Capitol Hill reservoir; not treated.
12. Tap in City chemical laboratory.

All samples were iced immediately upon collection and kept in this condition during transit and until arrival at destination.

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Samples examined by Dr. Ekeley, University of Colorado at Boulder, were about one hour in transit, and those sent to the Experiment Station, Fort Collins, were approximately three hours on the way. All samples were plated inside of twelve hours after collection.

Duplicate plates were made for the agar and gelatin counts, and in testing the waters for the presence of *Bacillus coli,* one 1/10 c. c. portion, one 1 c. c. portion and five 10 c. c. portions were used on all waters, and for the raw waters additional higher dilutions of 1/100 and 1/1000 c. c. were employed.

Each laboratory carried out the examinations according to its own particular routine, which was essentially the same thruout except for the medium used in the fermentation tubes for the *B. coli* tests. On this point the four laboratories differed: One used lactose broth; another, fresh ox bile; another "Bacto-bile"; and still another, dried ox gall. In spite of this lack of uniformity in methods, the results of the examination are strikingly uniform.

In Tables I, II and III, on pages 11, 12 and 13, the data from the four laboratories are given in detail.

Little comment is necessary on these results other than to call attention to the excellent and safe condition of the filtered and treated waters as shown by the low gelatin and agar counts and by the total absence of *B. coli* from the main supply, complying in all respects with the standard adopted by the Public Health Service of the U. S. Treasury Department.

Additional evidence of the excellent quality of the Denver water is to be had in the low death rate from typhoid fever, particularly during the past few years, amounting to only 8.57 per 100,000 population for 1914, and 6.72 for 1915. A diagramatic representation of the decrease in typhoid death rate for the past ten years is shown on page 14.

Denver is peculiarly fortunate in having at its service a corporation like the Denver Union Water Company, which unquestionably has the health of her citizens at heart as is clearly manifested by the minute precautions that are taken to insure the purity of the water; furthermore, in visiting the different plants and grounds of the Company, one cannot fail to be impressed with the business-like methods of operation and the splendid condition of the property—lawns beautifully kept, unsightly ditch banks in flowers, buildings, bridges, pipelines and equipment well painted, ditch banks and drives free from weeds and rubbish, and last but not least, the interior of the filter houses clean and sanitary.

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COMPARATIVE RESULTS OF CO-OPERATIVE INVESTIGATION
Samples Collected November 11, 1916.

Table No. I.—Number of Bacteria per c. c. on Gelatin at 20° C. after 48 hours.

Sample No.	Source	Jno. B. Ekeley State Chemist U. of C.	W. G. Sackett Bact. Colo. Ag. Exp. Sta.	Dr. W. C. Mitchell Bact. City & Co. of Denver	H. I. de Berard Chemist D. U. W. Company	Average
1.	Mississippi Av. Infiltration Galleries Inlet W. D. Res.	6	14	16	7	11
2.	Platt Riv. Raw —Intake Marston Lake—48" Cond.	165	2080	1400	1325	1240
3.	Bear Cr. Raw—Intake Marston Lake—Flume ...	1400	5400	Liq	4850	3880
4.	Marston Lake—Outlet N. S. Plant—Raw	435	750	300	600	520
5.	Marston Lake N. S. Plant-Treated	6	19	16	16	14
6.	P. C. Infiltration Galleries—30" Cond.	58	96	8	74	59
7.	Slow Sand Filters, Treated —40" Cond. Wynetka	54	12	53	75	49
8.	Willard Rapid Filters, Treated —34" Cond. Wynetka	6	43	9	62	30
9.	Marston Lake So. Side Plant —Treated—48" Cond. Wynetka	8	20	12	23	16
10.	Drinking Fountain in City—Cor. 1st & Bdwy.	18	41	20	57	34
11.	Cherry Cr. Infiltration Galleries—Cap. Hill Res.	(Bottle Broken)	1	5	1	2
12.	Tap in City Chemical Laboratory	51	25	21	69	42

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COMPARATIVE RESULTS OF CO-OPERATIVE INVESTIGATION
Samples Collected November 11, 1916.

Table No. II.—Number of Bacteria per c. c. on Agar at 37° C. after 24 hours.

Sample No.	Source	Jno. B. Ekeley State Chemist U. of C.	W. G. Sackett Bact. Colo. Ag. Exp. Sta.	Dr. W. C. Mitchell Bact. City & Co. of Denver	H. I. de Berard Chemist D. U. W. Company	Average
1.	Mississippi Av. filtration Galleries, Inlet W. D. Res.	2	1	Cont.	1	1
2.	Platt Riv. Raw —Intake Marston Lake—48" Cond.	17	51	73	68	52
3.	Bear Cr. Raw— Intake Marston Lake—Flume ..	61	76	68	280	121
4.	Marston Lake— Outlet N. S. Plant—Raw ...	27	36	25	104	48
5.	Marston Lake N. S. Plant-Treated	6	5	11	12	8
6.	P. C. Infiltration Galleries—30" Cond. Wynetka .	1	1	6	2	2
7.	Slow Sand Filters, Treated —40" Cond. Wynetka	2	0	7	7	4
8.	Willard Rapid Filters, Treated —34" Cond. Wynetka	4	2	5	2	3
9.	Marston Lake So. Side Plant —Treated—48" Cond. Wynetka .	2	0	3	3	2
10.	Drinking Fountain in City— Cor. 1st & Bdwy.	3	3	17	11	8
11.	Cherry Cr. Infiltration Galleries—Cap. Hill Res.		1	5	1	2
12.	Tap in City Chemical Laboratory	4	0	6	7	4

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COMPARATIVE RESULTS OF CO-OPERATIVE INVESTIGATION

Samples Collected November 11, 1916.

Table No. III.—Number of Bacillus coli per 100 c. c.

Sample No.	Source	Jno. B. Ekeley State Chemist U. of C.	W. G. Sackett Bact. Colo. Ag. Exp. Sta.	Dr. W. C. Mitchell Bact. City & Co. of Denver	H. I. de Berard Chemist D. U. W. Company	Average
1.	Mississippi Av. filtration Galleries, Inlet W. D. Res.	0	0	0	0	0
2.	Platt Riv. Raw —Intake Marston Lake—48" Cond.	10	10	6	10	9
3.	Bear Cr. Raw—Intake Marston Lake—Flume ..	10	10	6	100	32
4.	Marston Lake—Outlet N. S. Plant—Raw	6	0	6	6	4.5
5.	Marston Lake N. S. Plant-Treated	0	0	0	0	0
6.	P. C. Infiltration Galleries—30" Cond. Wynetka .	0	4	2	2	2
7.	Slow Sand Filters, Treated —40" Cond. Wynetka	0	0	0	0	0
8.	Willard Rapid Filters, Treated —34" Cond. Wynetka	0	0	0	0	0
9.	Marston Lake So. Side Plant —Treated—48" Cond. Wynetka .	0	0	0	0	0
10.	Drinking Fountain in City—Cor. 1st & Bdwy.	0	0	0	0	0
11.	Cherry Cr. Infiltration Galleries—Cap. Hill Res.		0	0	0	0
12.	Tap in City Chemical Laboratory	2	0	0	0	0.5

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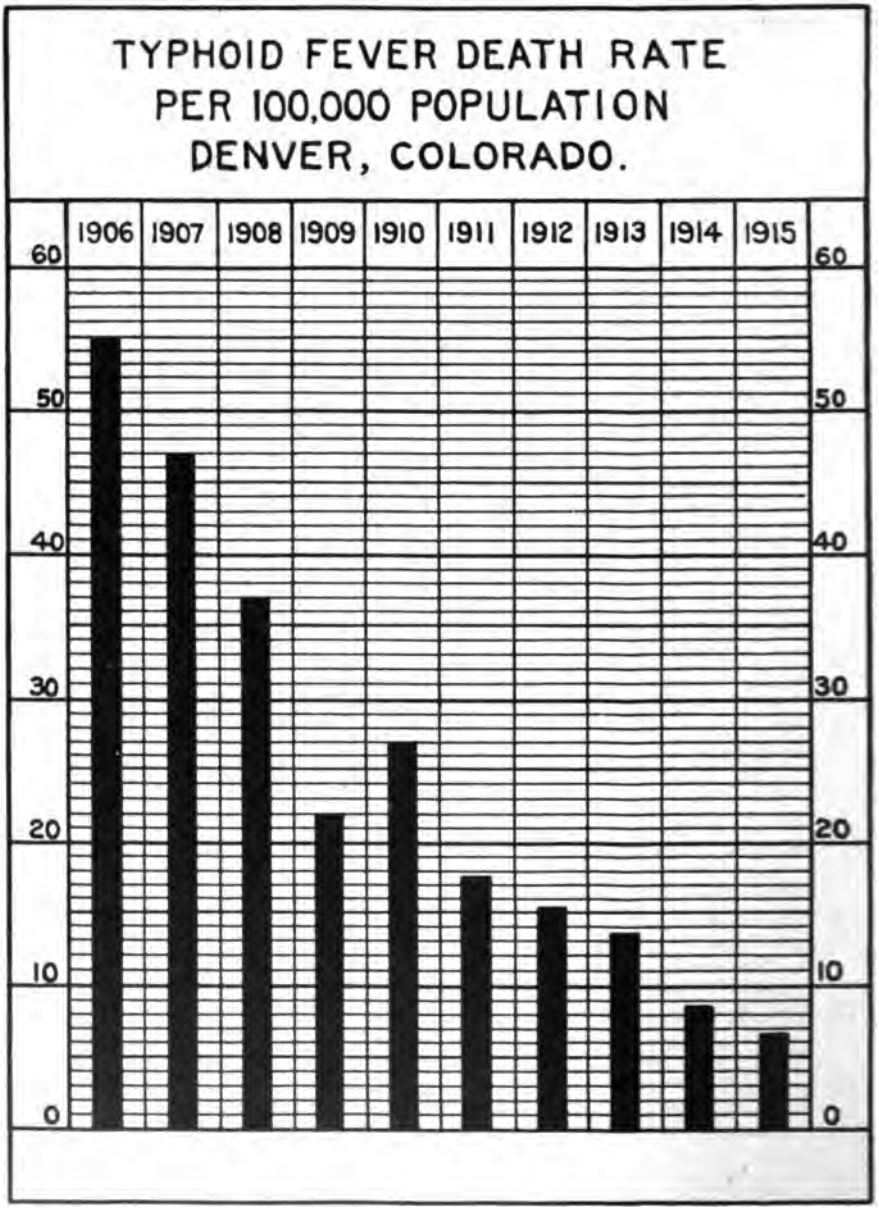

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Bulletin 226 March, 1917

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

BEANS IN COLORADO AND THEIR DISEASES

By

ALVIN KEZER and WALTER G. SACKETT

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1917

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BEANS IN COLORADO

By ALVIN KEZER

SUMMARY

Beans are becoming an increasingly important crop in Colorado.

They are well adapted for both dry farming and irrigated conditions.

The "Plains" section is almost entirely adapted for the growing of beans. They do well also in mountain valleys at altitudes not to exceed 7,000 feet. In many localities 6,000 feet is too high for their proper growth because of the shortness of the season and the tendency of early and late frosts.

Beans are an excellent cash crop, with a well established market and market facilities.

In Colorado the chief market bean is the pinto. Navies, teparies and the Red Mexican or Red Miner are grown to some extent.

Many beans are being grown under contracts with seed houses. These beans represent a number of different varieties produced for seed, because of peculiar advantages for clean seed which the semi-arid climate possesses. The chief danger of seed bean contracts is injury to standard markets by growers attempting to throw rejected seed onto the standard markets.

Beans are a hot weather crop, consequently, they should not be planted until frost danger is past. In most localities this will be approximately June 1st.

Planting should be shallow. Planting may be done preferably with the regular bean planters. Corn planters with bean plates may be used. The ordinary grain drill, stopping the proper number of holes, is feasible where necessity requires.

Beans are a shallow-rooted crop. Consequently, the first cultivation should be the deeper. Later cultivation should be as shallow as the first cultivation, or even shallower. Cultivation should not be over 3 inches.

In irrigated districts, beans should be irrigated so as to keep the beans growing. A very dark green color is generally indicative of a need of water. Beans should not be irrigated later than full bloom on most soils, as later irrigation will delay maturity

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and not increase yield materially. Ordinarily one to two irrigations are sufficient.

Harvesting should be done preferably with a bean harvester. This is especially true where any considerable acreages are planted. On very small acreages, they may be harvested by taking the mold board off the plow or by using a shovel.

Beans shatter in thrashing very easily, consequently the bean huller should be used unless the acreages are very small. There are special attachments which may be used on the regular grain separator, provided the separator is run at very low speed. Patches of one to two acres can be thrashed with a flail as cheaply as by machine unless a machine is near. Machines for cleaning are available and should be used, as they increase market value.

Pinto beans, the chief Colorado market sort, will average from 300 to 800 pounds under dry lands and may yield as high as 1,800. The same beans will average from 1,200 to 2,000 pounds under irrigation, and may yield as high as 3,000 pounds or even above.

Market prices may be increased by putting beans up in uniform packages and having them thoroly cleaned.

Bean straw should be carefully saved, as it is a valuable feed. This applies especially to dry lands.

Beans make an excellent rotation crop. Wheat on the dry land after beans will do as well as after clean summer fallow most seasons.

The yield of beans may be increased and their quality improved by wise field selection.

Seed beans should be hand picked to get uniform quality and freedom from disease. Care should be taken not to plant beans which have been frost bitten.

There are many diseases which affect beans. The best methods of controlling these diseases is the picking of clean seed and following a rotation. Beans should not be planted on the same land two years in succession. Two to three years should elapse before beans are again planted on the same land.

INTRODUCTION

The Colorado bean acreage has been steadily growing for the last ten years. The rate of growth in 1915 and 1916 has been as great as in the previous eight years. According to the Bureau of Statistics, United States Department of Agriculture, 38,000 acres were grown in Colorado in 1916, a jump from 21,000 acres in 1915, and 20,000 acres in 1914. The total production of the State in this period has jumped from 18,000,000 pounds to 25,440,000 pounds, in round numbers. In other words, the acreage has increased 81%

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and the total production has increased in the same period about 41%. The 1916 yield per acre was low on account of one of the worst drouths in the history of the Colorado Plains. The seasons of 1914 and 1915 were especially favorable, with high average acre yields.

Beans are well adapted for growing in nearly all sections of the plains. Beans are a hot weather crop and as a consequence must be produced in the frost-free period. To successfully produce a bean crop, the season should be at least 95 days in length; 95 to 100 days should be the minimum. A season of this length is seldom found above an average of 6,000 feet in elevation. There are localities where the slopes are favorable and the soils sandy, where the seasons are somewhat longer, permitting the production of beans at altitudes as high as 7,000 feet. If the season is bright and rather warm, some of the early varieties may be matured in as short a season as 60 days. A cloudy season, however, always lenghtens the growing period. Cool, cloudy weather may extend the growing season, especially if rains accompany these weather conditions or if irrigation is given. In such cases the season required for maturity may be as long as 130 days, too long for many sections even 6,000 feet in altitude.

The pinto bean, which formerly went under the name "Mexican", is by far the most important market bean, as it exceeds in acreage and total production all other beans produced. The seed industry beans, which are of numerous varieties, are the only ones which begin to compete in acreage with the pintos. These seed beans are largely produced under contracts with seed houses and consequently do not reach bean markets.

While beans may be successfully grown practically anywhere on the plains, at altitudes below 6,000 feet, they are most abundantly grown in Weld County and Las Animas County. They may be as successfully grown in other places, but development in other regions has not yet been carried to the extent which these two counties have made. The realization of the value of beans as a cash crop, and the ease with which they fit into a rotation by throwing in an annual cultivated crop, will very likely tend to increase their general production.

VARIETIES

The chief market variety is the pinto. The pinto bean was formerly called the Mexican. This name, however, is inappropriate, as there are numerous other Mexican varieties. The name "Mexican" as a consequence did not mean any definite bean. "Pinto" applies to a specific bean.

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The pinto bean is about the same shape as the kidney bean, so well known as a garden variety. It is also about the same size as the kidney bean just mentioned. The pinto is buff-colored, is speckled with tan to brown spots and splashes. In many places in the southwest the pinto is called the Mexican tick bean. The name "pinto", however, has become so well established that it should be universally used.

While the pinto is the chief market bean, other beans are grown and frequently do well. The navies are grown and produced to a small extent—both the pea bean and the little navy. For garden purposes considerable quantities of kidney beans and "snaps" are grown. In most of our territory the season is too short for the proper development of limas; consequently, they do not figure in our bean problem to any extent. In parts of Colorado the Red Mexican or Pink Mexican, or Red Miner, is grown. This bean, however, is more extensively grown in New Mexico and Arizona and other points of the Southwest than in Colorado.

PREPARATION OF THE SOIL

Beans will grow on almost any kind of soil, from adobes to light sandy loams. They do best, however, on warm, sandy loams and sandy silts. Preparation of the soil for beans should commence prior to the season in which the beans are grown and should take into consideration proper rotation and manuring. The soil should be prepared by plowing. Wherever fall plowing may be done without danger of serious fall blowing, the soil should be plowed in the fall. In the spring this land should be worked down into a seed bed, making as good a seed bed as would be made for beets or corn. Where spring plowing is done it should be done early.

Beans respond to good preparation. Consequently enough attention should be paid to disking, harrowing and compacting the seed bed. In some sections listing has been attempted as the method of preparing the soil for bean planting. Listing, however, is poor practice, except upon soils which cannot be safely plowed, because of their very strong tendency to blow. Where the land is prepared by listing, there is a tendency to slow up the development of the crop and delay maturity. In addition to these handicaps, beans planted by the listing method are more difficult to harvest; especially if there is damp weather during the harvest there is likely to be much damage to the pods by coming in contact with the soil. The tendency to pick up adobe soil or stones is increased at harvesting time. If listing is done at all, it should

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be very shallow so as to make the furrow to be filled about the growing plants as shallow as possible.

It is not always necessary to plow land in preparing a bean seed bed. Where the land was well plowed the year previous and in wheat, a good seed bed may be prepared without plowing, provided the wheat stubble is disked right after the binder to keep down weeds in the fall. The spring preparation may consist of disking when the weeds start, which will destroy the weeds and prevent the formation of a crust, and then disking and harrowing immediately before planting. After a cultivated crop such as corn, which has been well cultivated, a seed bed may often be prepared by disking and harrowing.

On irrigated lands after sugar beets or potatoes, it is not necessary to plow in preparing a bean seed bed. Disking, leveling and harrowing will be sufficient in these circumstances.

PLANTING

Care in Selecting Seed Beans.—The importance of getting good seed beans is sufficient to warrant special care in picking the seed. It is worth while taking a little extra care in Colorado on account of the short seasons. In many localities there is danger of beans being frost bitten in the early fall. Sometimes this light freezing will very materially weaken the germ so that the crop will have very small germinating power, altho the frost may not be sufficient to injure the beans seriously for market purposes. Care should therefore be taken not to use beans for seed which have been frost bitten before full maturity.

Many of the diseases which affect beans leave spots on the beans themselves. One of the most effective remedies in combatting bean diseases is to pick out plants for seed which are not affected by the disease. Accordingly all seed beans should be from plants selected in the field and hand picked. Plants having discolored beans with strange colored spots should be rejected, planting only from those having bright, clean seed.

These statements hold, no matter what variety of beans are planted.

Time to Plant.—Beans are a hot weather crop. Seed is injuriously affected if it is planted in cold soil. Germination will not take place while the soil is cold, and if the soil happens to be wet enough, rotting may take place before the soil warms up sufficiently to permit germination.

Beans will not stand any frost. The very slightest degree of frost is apt to kill them entirely. On account of these reasons, beans should not be planted until the soil is thoroly warmed up.

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In most Colorado sections this will be the last week in May or early in June. Successful plantings have been made as late as the first week in July, but the grower is tempting fate too much to make a practice of such planting, as frosts are likely to occur as early as the 25th of August.

While pinto beans and some of the teparies and a few of the Mexican and Indian varieties have been matured in 60 days or less, it normally takes about 90 days to mature a crop even for these short-season beans. In those seasons when frosts hold off until late in the fall, late planting will often make a crop, but frosts do not always hold off until late.

Method of Planting.—If there is any considerable acreage of beans to be put in, a bean planter should be procured, or a corn planter with bean plates. In Colorado beans should always be planted in drills so that the bean planters or corn planter should be so arranged as to drill the seed one in a place. It is possible to make use of a grain drill by stopping up the proper number of holes, in fact, many beans are successfully planted with such an implement. The type of grain drill having a revolving cup feed is adapted for this kind of planting.

Most of our grain drills have 7 or 8 inches between the drill holes. Stopping up three drill holes would therefore plant 28 inches apart, which is about right for irrigated planting. With a 7-inch drill, stopping up five holes, that is, leaving open the first and sixth drill, would plant 42 inches apart, which is about right for dry land. Some dry lands are strong enough to justify planting 36 inches apart. Stopping up four drill holes, leaving the first and fifth open, would plant 35 inches apart, which is about right.

Under irrigated conditions the rows should be about 28 inches apart. On dry lands, they should be from about 3 to 3½ feet apart. Under very dry conditions it is sometimes advisable to plant 7 feet apart and cultivate all of the intervening space. For irrigated conditions the drill should be thick enough to make one plant every 4 to 6 inches. This will require around 30 to 35 pounds per acre of seed for pinto beans. It will require a greater number of pounds for larger beans and a somewhat smaller number of pounds for the small pea beans.

For dry land conditions beans should, under normal conditions, be planted in rows about 3½ feet apart and in drills in the row 10 to 12 inches apart. If dry land conditions are a little severe, or uncertain, the space can be made a little further in the drills, say from 12 to 16 inches. According to the rate of drilling, it would take from 8 to 20 pounds of seed to plant an acre under dry land conditions. For an average planting, probably about 15

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pounds per acre will be used. Where the rows are made 7 feet apart, under very severe conditions, the planting should be 6 to 8 inches in the drills.

Of the many beans planted only a few are put in by plowing shallow and dropping the beans in every third or fourth furrow, covering the beans by plowing and then packing and harrowing afterwards to compact the surface soil over the beans. This is not a good practice, but can sometimes be used in very small patches. Where large plantings are made, a bean planter adjusted to plant in exactly the proportion desired, should be used.

CULTIVATION

Beans of all varieties are rather shallow-rooted surface feeders. Consequently all cultivation after the crop starts should be shallow. The most important part of the cultivation should be done in the preparation of a seed bed. Immediate cultivation should commence about the time the rows can be seen in the field. Where the stand is extra good, beans may sometimes be harrowed a time or two if care is taken to do this work when the young vines are perfectly dry. If the soil is a little moist and the vines moist, the young vines will be found to be quite brittle so that harrowing will break off a large number. With the surface of the soil rather dry and the plants dry, the young plants are tough and will stand harrowing.

Some of the weeders on the market are excellent tools to use at this time.

The first cultivation with the regular cultivator should be the deepest. This first cultivation should not be over 3 to 4 inches

Cultivating dry-land pinto beans in El Paso County

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deep. Later cultivations should be as deep or slightly shallower than the first cultivation. When the first cultivation is made, the roots have not extended very far into the space between rows. The stirring of the surface layer at that time by the cultivator makes a dry layer on top. If this is maintained the beans will root below the dry layer. Cultivation should be aimed primarily to keep down weeds and prevent the formation of a crust. Usually all cultivation should cease by the time the first pods commence to set. Sometimes the plants have grown enough so that cultivation should cease before this time. Care should be taken never to cultivate when the young bean plants are wet, as they are easily broken at such times, and when so broken are very susceptible to certain bean diseases. Under irrigated conditions cultivation should follow irrigation, as soon as the surface moisture and the plants will permit. The aim should be to prevent the loss of water by cultivation rather than to furnish water by excessive irrigation.

Irrigating Beans.—A study has been made of bean irrigation in eight Colorado counties. This study shows conclusively that it is fully as easy to over-irrigate beans as to under-irrigate them. As an average of all results obtained, two irrigations give higher yields than three or more irrigations. There was some difference as to quality of land; very open gravelly lands would stand more irrigation than sandy loams, loams and clay loams.

In irrigated regions beans should be given water when they show a need for water, namely, when the plants show a very dark green and commence to wilt during hot periods of the day. If the plants are light green and growing vigorously, irrigation may often be delayed unless it is necessary to irrigate to get the water.

Beans in irrigated districts will usually be planted in rows around 24 or 28 inches apart. The first step in irrigation is to use a furrow opener and make furrows between the rows. Water is run down these furrows under proper control, until the soil is moistened laterally and to a depth of at least 2 feet. This figure 2 feet is a relative one. Sometimes there is moisture enough in the subsoil at less than 2 feet from the surface when the surface needs irrigation. In such cases a lighter run of water will suffice. The last irrigation should very seldom be given after the blooming period; just as the plants are coming into bloom is as late as water should be applied in ordinary seasons, and on ordinary soils. Later irrigations delay the maturity of the crop and endanger proper ripening, because of possible frost injury. Such later irrigations do not materially increase the yield of beans.

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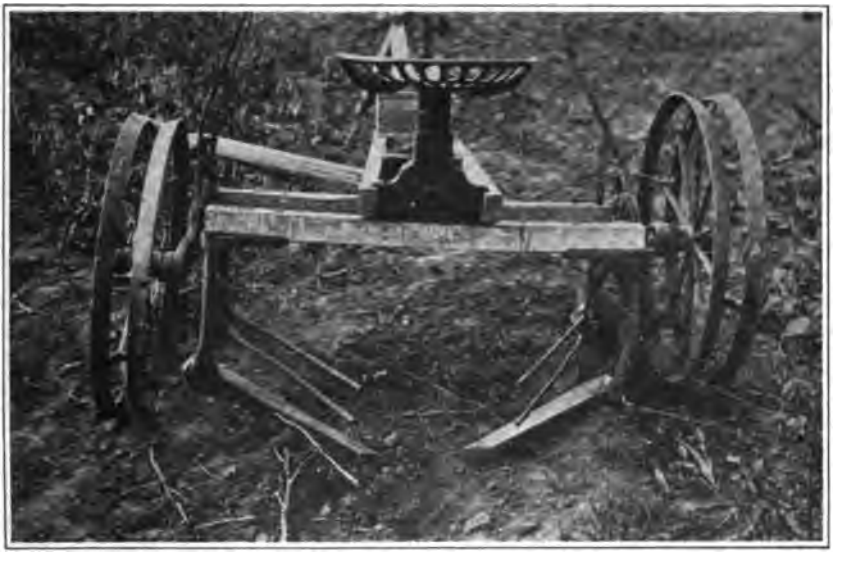
The chief consideration, either on irrigated land or dry land, is good thoro cultivation. Such cultivation should be given as soon after irrigation as possible to get onto the land, and on dry lands such cultivation should be given after rains as soon as it is safe to work the soil. Cultivation should not be given after the vines begin to run, which is about the blooming period, as previously mentioned.

HARVESTING

All harvesting methods can be classified into hand harvesting and machine harvesting.

Hand harvesting is only adapted to small patches. Hand harvesting is usually done by either pulling the vines or cutting them off just under the surface of the ground with a sharp shovel. The vines thus pulled or cut off are shocked by means of pitch forks.

The best machines for harvesting beans are the regular bean harvesters. These machines cut the bean plants off just below the



A common type of bean harvester

surface of the ground and by means of fingers push two rows together into one harvested row. The most up-to-date machines have bunching devices on the machine which bunch the cut vines into small, neat bunches. These bunches can be dressed up a little by a man with a pitch fork, for curing. Many of the machines, however, have no bunching device. In this case the bunching must

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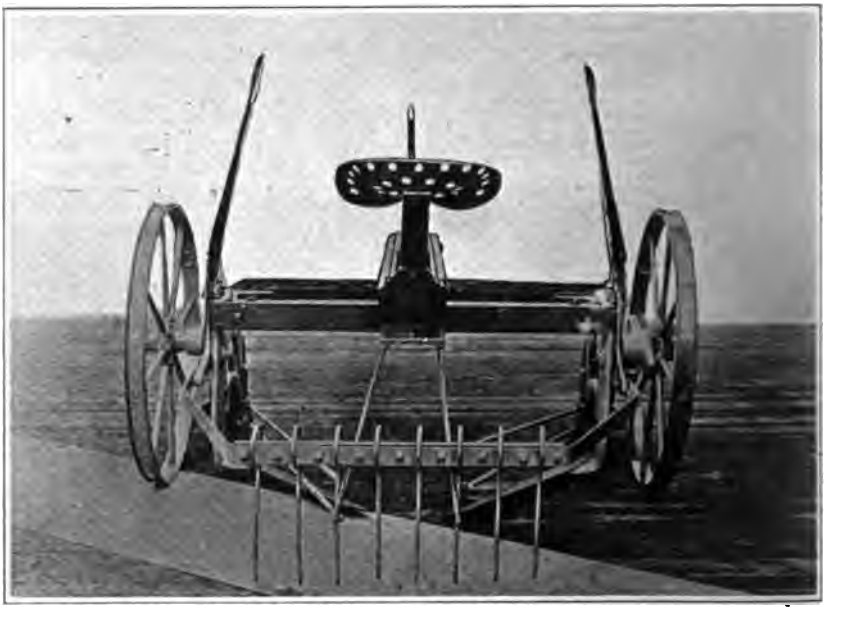
be done by hand. Men follow the machine with pitch forks putting the cut beans into neat shocks.

While a regular bean harvester is desirable and should always be used if there is any considerable acreage of beans grown, they may be harvested by using a breaking plow of the rod type, or by using a common sod plow with the mold board removed. Such expedients are much better than hand work on patches an acre or more in size, but should only be used on small patches where the size of the patch is not large enough to justify the purchase of a regular harvester.



One of the newer bean harvesters with bunching attachment

Harvesting Period.—Opinions differ as to the proper time of harvesting. But experience and experimental work both show that if the beans are allowed to become completely ripe on the vine, heavy loss occurs from shattering. A good rule to follow is to harvest when the pods are turning yellow but have not yet dried out; at this stage there will usually be about half of the pods yellow ripe and a few still showing some green, providing the beans are ripening uniformly. When cut at this yellow-ripe stage, the beans will ripen up in the shock during the curing process and the loss in weight by drying out is very much less than the

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loss in weight thru shattering if the beans are allowed to become too ripe.

Care of Harvested Beans.—The beans thus cut with the harvester should be made into small shocks. The height of the shock will be just as high as possible, and have the shock stay erect. In windy plains sections small round shocks are less likely to be blown away or thrashed out by blowing. In drying weather the shocked beans will cure rapidly. If it is impossible to thrash them when cured, it would be far better to stack them in neat stacks so as to prevent loss by blowing, discoloration from weather conditions and also to leave the land free for cultivation. If the beans have been properly shocked, there will be very little shattering in stacking as the stacking can be done early in the day,

A good field of dry-land pinto beans ready for harvest

or loss may be prevented by covering the hay rack or bean rack with canvas. In building a stack a bottom should be made with straw and the stack should be topped out with straw and weighted. If straw or millet is not at hand to be used for this purpose, a stack cover of canvas or corrugated iron will be advisable if any considerable time is to elapse before thrashing.

The harvesting process, together with summer cultivation, leaves the land in excellent shape for fall planted crops such as wheat, or even for spring planted crops, as plowing is not necessary after the tillage given the beans.

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THRASHING

Beans split very easily unless handled with care. Split beans are docked on the market. Consequently, tools should be used which split the minimum of beans. It is for this reason that the regular bean hullers or bean thrashers should be used for thrashing the crop.

There are a number of manufacturers having bean hullers on the market. It is possible by using some of the modern attachments to thrash beans with the regular grain separator. This should not be done unless a bean huller is so expensive, acreage considered, as to make it inadvisable. Where the grain separator is used to thrash beans, special attachments are put in and the cylinder is run at a very slow speed. Usually all the concave teeth with the exception of one row are removed.

Where a grower has only one-half an acre, or one acre, it is sometimes easiest and cheapest to thrash out his beans with a flail. Fifteen to eighteen hundred pounds a day can be thrashed out in this way by a single man.

Very few of the thrashing machines on the market will properly clean beans for the market. Consequently, machines called bean cleaners have been devised to clean up the beans ready for marketing. If any considerable acreage is grown, it would pay to have a bean cleaner to clean the thrashed beans before they are put on the market. Where only small acreages are grown, neighbors might well co-operate in the purchase of a cleaner, as one cleaner would do the work for several small growers.

YIELD

The Colorado pinto is the great market bean for Colorado. As has already been said, it is grown on more acres than all other kinds of beans combined. The average yield of pintos per acre on the dry lands in 1914 and 1915 was close to 800 pounds. In 1916 the average varied from 300 to 600 pounds per acre, with total failures in some neighborhoods. The season of 1916 was one of the driest in the history of the Colorado plains. The average yield of Colorado pintos on irrigated lands in 1914 and 1915 was 1,400 pounds per acre. In 1916 the average pinto yield under irrigation was close to 1,600 pounds per acre. Yields as high as 2,000 pounds per acre have been produced on the dry lands and as high as 3,200 pounds have been produced on irrigated lands. These higher yields are by no means average, but they show the possibilities of the crop when all conditions are made favorable.

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A good set of pinto beans; after a light frost

MARKETING

One of the most important problems in the marketing of beans is to have a clean, high-grade, uniform product. Mixed beans, with discolored, broken beans, seriously docks the price. Since the pinto outyields most other beans in practically all the Colorado bean-growing sections, it should constitute the chief market bean.

Machine-cleaned pintos will usually sell on the market within a cent of the price asked for hand-picked navies. The actual net return on pintos will usually be higher than for navies, because the cost of cleaning is not so great and the rejections under good market conditions are a great deal less.

In abnormal years, like 1916, buyers will take almost any kind of a bean, but even in 1916 buyers were paying a premium for uniform lots of clean, well-graded pintos. In some localities pintos are handled in bulk. Where this is true a uniform grade and cleanness should prevail in the bulk delivered. Many bean markets, however, require that the beans be bagged for shipment. Where such is the case, the beans should be thoroly cleaned and graded. Uniform, standard quality should be bagged in bags of uniform size and marking. The marking suggested is "100 Pounds Colorado Pintos". The remaining marking can specify the grower and address when so desired.

Growers will be able to receive much better prices where a uniform product is produced and where the entire neighborhood

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is growing one kind of bean. This is due to the fact that the marketing costs are lower under such conditions.

With the exception of one season, Colorado pintos have netted the growers around 4 to 4½ cents for the past eight or ten years. In 1916, prices much higher than this prevailed. But 1916 prices were as abnormally high as 1912 prices were abnormally low. At 4c a pound to the grower, pintos constitute a reliable cash crop which will return good acre net profits to the grower.

The red Mexicans, the spotted Indian beans and teparies do not have a standard market in this section. They are grown extensively in the Southwest. In fact, the pink bean in southern California, Arizona and New Mexico is quite generally grown and is perhaps the most common bean on the market, but for those sections to which Colorado normally ships, namely, the South and East, pintos and navies are the types known. Navy beans may be successfully grown under Colorado conditions, but they require much more hand work and care. Consequently, they are much more expensive to produce. While they bring higher prices on the market, the spread between navies and pintos is usually not over one cent. This spread will be more than obliterated by the increased cost of preparing navies for market. Besides, there will be a very much lower rejection in grading and cleaning from pintos than from navies, so that a greater proportion of the crop will actually reach the market.

Market grades have been established for the pinto beans. These grades have been adopted by the bean buyers' associations. It is quite probable that the Bureau of Markets may standardize grades for this crop. When such is done, it will be much easier for growers to prepare a standard product for the market. A standard product can be marketed to a better advantage than an unstandardized product, because very much less inspection is required to determine the quality of the product offered, where beans are so standardized and graded as to permit them to be sold on grade and sample without the necessity of sampling each individual bag.

Communities could do much in helping out their market problem by growing uniform quality and following market demands as to package and cleaning.

COST OF PRODUCING BEANS

It is impossible to give exact figures which will really represent the cost of producing beans, as so many factors enter into the cost of production on different farms. On dry land it was found that beans could be raised with as little labor as corn. The aver-

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age amount of labor, therefore, required to produce an acre, would be equivalent to about 15 man hours per each acre of beans per year, and about 42 horse hours. The labor cost of producing a bean crop on the dry lands will probably run from a minimum of $5 to a maximum of $8 per acre. To this labor cost must be added interest and depreciation on machinery used and interest on the land or rentals.

The cost of producing beans under irrigation will give a labor cost somewhat higher, running from $9 to $15 per acre. Under irrigation, in addition to machinery costs, which will be quite comparable to those on the dry land, there will be added the cost of irrigation, water rentals or ditch up-keep. Land rentals, or interest on land investment will be consequently higher.

It is possible that where a farmer does all his own work, he will be able to produce beans on the dry lands for from $5 to $7 per acre, and under irrigation for from $15 to $30 per acre, depending upon the locality and land conditions and land values. If all labor must be hired, it is quite possible that the efficiency of labor will be lower and the price somewhat higher than normal going wages in dry land and irrigated regions because if all labor is hired, it will usually be wanted at times when everybody is busy and as a consequence more will have to be paid for the labor. This will likely raise these estimated costs somewhat.

For two years, during which studies were made on the dry lands, it was found that the cost of operations for the production of beans varied from a minimum of $2.15 per acre to a maximum of about $6 per acre. The cost of operations included the cost of all horse and man labor and does not include seed costs, interest and depreciation on machinery or land rentals. The differences in cost were due to differences in number of cultivations and the manner of preparing the seed bed. In computing these costs, 15c per hour was allowed for the value of man labor and 10c per hour for horse labor. Where the farmer is doing the work himself, if he allows these costs, he is, of course, paying himself wages at these rates. Labor is occasionally cheaper than these prices and in rush periods is often higher. The figure given was found to be the average paid in dry-land regions for two successive years, the average being the average wages paid for the entire season, and not the average paid during rush periods.

USE OF BEAN STRAW

The bean straw and hulls after the beans have been thrashed out will yield from one-half to three-quarters of a ton per acre on dry lands, and somewhat heavier yields will be received from

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irrigated lands. This bean straw is capable of utilization. Especially on the dry lands every bit of bean straw should be saved and fed. Enough experience has already been obtained to indicate that on the dry lands if bean straw is fed with silage that it will return a food value nearly as great as alfalfa. If the bean straw is fed with other dry feeds, it is not as valuable as alfalfa. In fact, it appears to return about one-half the feeding value if fed with dry feeds, and almost as much as alfalfa when fed with succulent feeds. The utilization of bean straw, therefore, constitutes a very material addition to the feed supply under dry land conditions.

BEANS IN ROTATION

Under irrigated conditions, beans furnish an opportunity for a cultivated cash crop, which is their chief value in irrigated rotations. Some types of weed pests can only be cleaned up where a cultivated crop can be introduced. Beans furnish such a crop, which may not only be cultivated, but hoed. On the dry lands, however, beans have a still greater value, because they furnish a cash cultivated crop well adapted for dry lands and capable of returning very good money values, dry-land possibilities considered. It has been found by experience that wheat, after a bean crop which has been well cultivated, will yield as well as after summer tillage or a summer fallow. Since they will usually pay well for growing, beans may be produced on lands which in many cases would be without a crop.

On the dry lands beans have a tendency to build up the soil. If the bean straw is fed to livestock and the manure properly applied to the land, the beans will be a decided, positive asset. If bean growing is a part of the regular farming system, the beans themselves should be grown in rotation. There are many bean diseases which tend to not only reduce the yield of beans, but to reduce their salability. One of the best methods of fighting these diseases is to plant beans in rotation, that is, never plant beans two years in succession upon the same land. At least two or three years should intervene in order that the land may not become inoculated with the diseases which affect the bean crop.

IMPROVEMENT OF PINTO BEANS BY SELECTION

The greater proportion of the planting of pinto beans has been done with little or no seed selection. Sufficient experimental work has been done to show that as much progress may be made from selection with pinto beans as is sometimes done with corn in the corn belt. The bean plants are mostly self-fertilized, thus, if a good strain is once obtained, no further selection within

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the strain is necessary, because the strain is a pure line and breeds true. Every pinto bean grower who is making a business of bean production should start a seed patch. The start should be made by selecting plants in the field. In making selection, the following points should be watched for:

1. High individual plant yield
2. Early maturity
3. Uniform ripening of pods on the plant
4. Freedom from disease

To make a seed plat, the seed of each of these selected bean plants should be planted by itself in a row. These rows are really

A desirable type of plant—dry-land pinto beans

comparative tests of the value of the selections. The high-yielding rows which are produced represent the mother plants which it is desirable to keep. All the seed from high-yielding rows having other desirable characteristics should be saved. If one strain

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should prove to be very much better than all others, this should be saved for seed and increased to the fullest extent possible. In this way the entire bean acreage will soon be planted from this high-yielding, early-maturing, even-ripening, disease-free strain.

Preliminary work with bean selection shows that it is easily possible to increase the yield 25 per cent by selection alone. To increase the yield this much would pay for all of the extra work of starting a seed patch and testing out in comparative tests the various selections, thus enabling the grower to pick out the highest-yielding strain of his crop from which he may eventually plant his entire crop. It will pay to hand select seed to get seed of uniform marking, uniform size and freedom from disease, even if time and conditions do not permit the better work of the selection of pure, high-yielding strains.

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DISEASES OF BEANS

By WALTER G. SACKETT

As mentioned elsewhere, the growing of beans in Colorado for seed purposes is one phase of the industry which has developed at a remarkably rapid rate, considering the length of time that the crop has been raised with this in view. In all probability, one reason for this has been the desire on the part of the seedsmen to obtain seed grown under conditions which normally tend to reduce the percentage of diseased seed. Such conditions obtain to a greater or less extent in both the dry land and the irrigated sections of the State. The absence of moisture in the form of rain, which tends to spread disease over the plants and from plant to plant, together with abundant sunshine are both valuable assets to the localities where beans are being grown.

Another consideration which made Colorado a desirable place for raising seed beans was the fact that until two years ago the disease question was practically negligible. There was plenty of disease-free land, new so far as bean culture was concerned, on which there was good reason to believe that no difficulty would be experienced for years to come in the line of plant diseases. But the inevitable has happened, and in the remarkably short space of two years.

Someone innocently planted diseased seed from which unhealthy plants developed, and from these as a starting point, it has been a relatively simple matter for the infection to spread from vine to vine, plant to soil, and field to field.

Where irrigation is practiced, the irrigating water, flowing as it does thru infected fields, carrying more or less trash and diseased soil with it, cannot be lost sight of as a means of disseminating the various ailments to which the bean is heir.

Our severe and prolonged winds which may assume the form of sand storms, transport quantities of soil, irrespective of whether it is diseased or not, from one locality to another. The mechanical injury to the pods and beans which results from this incessant pounding by the sand grains, not only weakens the plant, but also opens up the way for subsequent infection with germ-laden soil particles.

Some growers have failed to use beans in a rotation and have planted beans after beans on the same land, having lost sight of

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the fact that, aside from this being poor farm practice, the dangers from disease are increased very greatly by such a procedure.

Little if any attention has been given either to the planting or the selecting of disease-free seed, with the result that we have built up a big seed business in a phenomenally short time, but a business which is destined to fail, as has been the history elsewhere, unless we can establish a reputation for our seed with respect to quality, purity and freedom from disease.

Now is the time to do this, before our fields become generally infected, and while the prevalence of disease is so slight that it can be controlled for the most part by the means that we have at our disposal.

For the present consideration, we shall confine the discussion of bean diseases to those which have been observed to occur in the State during the last two years, and which, if neglected, may prove a serious menace to the industry.

DESCRIPTION OF DISEASES

Bacteriosis or Bacterial Blight

Without doubt, the greatest damage to our bean crop during 1916 resulted from an attack of the bacterial blight. This is caused by a germ, *Pseudomonas phaseoli*, which enters the plants thru the breathing pores or stomata and thru wounds produced by mechanical injury.

The disease is common upon field, garden and lima beans and attacks leaves, pods, stems and seed. It is very conspicuous upon the pods and leaves and can be recognized most easily, perhaps, upon the former, particularly in the wax varieties. Here we find watery spots ranging in size from tiny specks to areas three-eighths of an inch and more in diamteer. They are usually irregular in outline and roughly circular in shape. On the wax varieties, the spots are translucent or watery, amber-yellow in color and frequently have a rosy-red margin. Their appearance, on the whole, is not unlike an ordinary blister, except that they are neither raised nor sunken. In the more advanced stages, they may be coated over with a thin, pale yellow or amber-colored crust which is composed largely of the bacteria which produce the disease. Ulcers in all stages of development can usually be found on a single pod. (See Fig. I.) When the lesions are numerous, they frequently coalesce, or run together, so that the whole side of the pod presents one continuous canker.

The injury to the leaves is very marked. In the early stages, irregular, watery spots can be found scattered over the surface

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Fig. I.—Bean pods affected with Bacteriosis or Bacterial Spot

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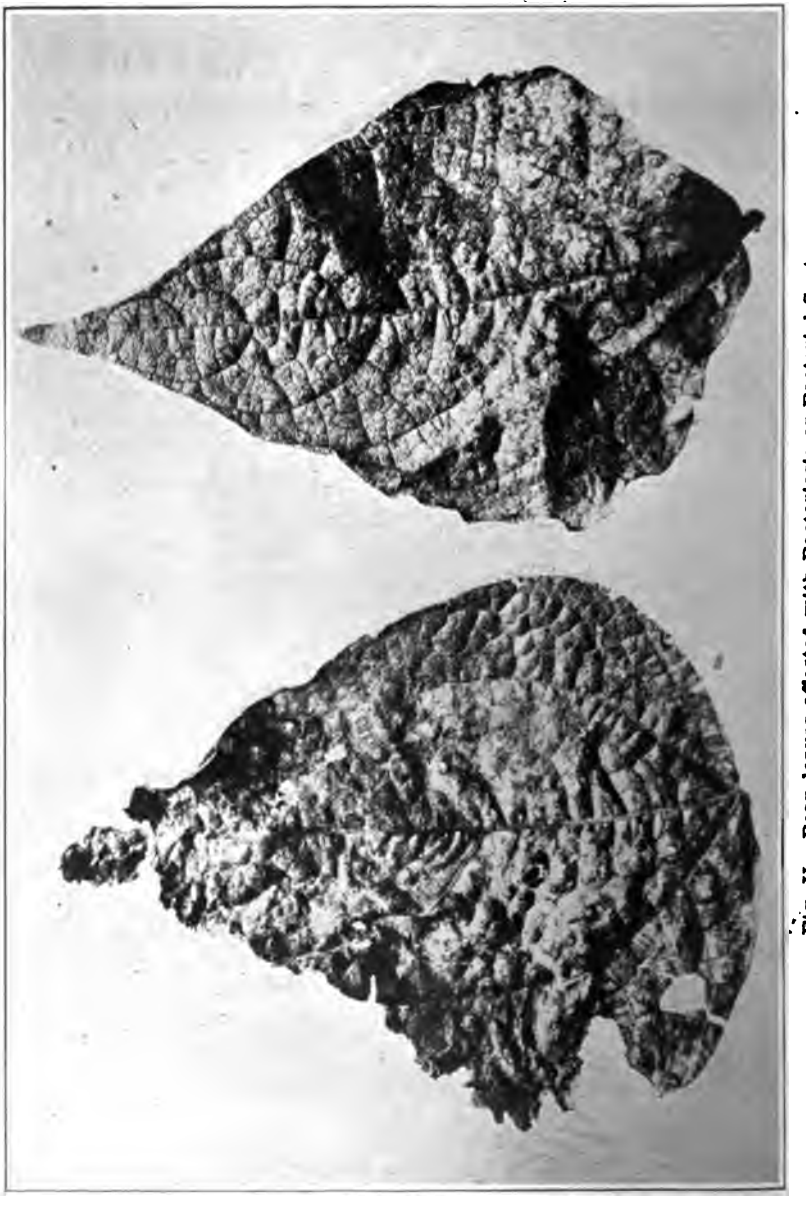

Fig. II.—Bean leaves affected with Bacteriosis or Bacterial Spot

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which soon turn yellow and in a short time become frosty-brown in color. If the spots are numerous they will often coalesce and give the dry, brown leaf a peculiar blistered appearance. (See Fig. II.) The tissue in this condition is extremely brittle and is easily torn and broken, which accounts for the ragged condition of blighted leaves. The stems are affected in much the same way as the foliage.

Badly diseased plants lose their leaves early and fail to mature their seed. Spotted pods are unfit for the market as green beans, and seed from them is very apt to be diseased as the infection is communicated to the seed from the pod.

Pod-Spot or Anthracnose

Pod-spot or Anthracnose has been of relatively little importance thus far in Colorado bean fields, but because of its ravages in other localities, it seems advisable to become acquainted with its symptoms in order that it may be recognized should it become serious.

The disease makes its first appearance on the seed-leaves and stems of the seedling plants. It manifests its presence there by brown, discolored, sunken spots or ulcers, indicating rather clearly that the causal fungus, *Colletotrichum lindemuthianum,* has been carried over winter in the seed.

In due course of time, spores, by means of which the disease is spread, are produced in these early spots. Eventually they are blown, or otherwise carried, to the growing stems, leaves and pods, where they soon become established and begin their destruction.

On the leaves we find reddish or blackened areas developing along the large veins on the under surface. The veins may be eaten thru by the fungus and destroyed, while the blade shows numerous cracks or holes with shriveled, blackened margins. Leaves in this condition are practically worthless as food-building organs, and as a result the nutrition of the plant is greatly impaired; either the yield of seed is reduced appreciably or the seed fails to mature.

Previous to the time of blossoming, the attack has been concentrated against the leaves, and by the time the young pods make their appearance the fungus has become well established and is amply supplied with spores. These soon find their way to the young, tender pods where they produce rusty-brown or black sunken spots with reddish or yellowish margins. (See Fig. III.) These vary in size, much as the bacterial spots previously described. The spores of the fungus are produced in the center of the black ulcers and form little pink masses visible to the naked eye.

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They are glued together with a mucilaginous material which sticks them securely to the spot. However, as soon as a drop of moisture touches them, the mucilage is dissolved and the spores are set free in the water. At this time any disturbance of the plant is apt to scatter the spores in the flying drop of water, and for this reason

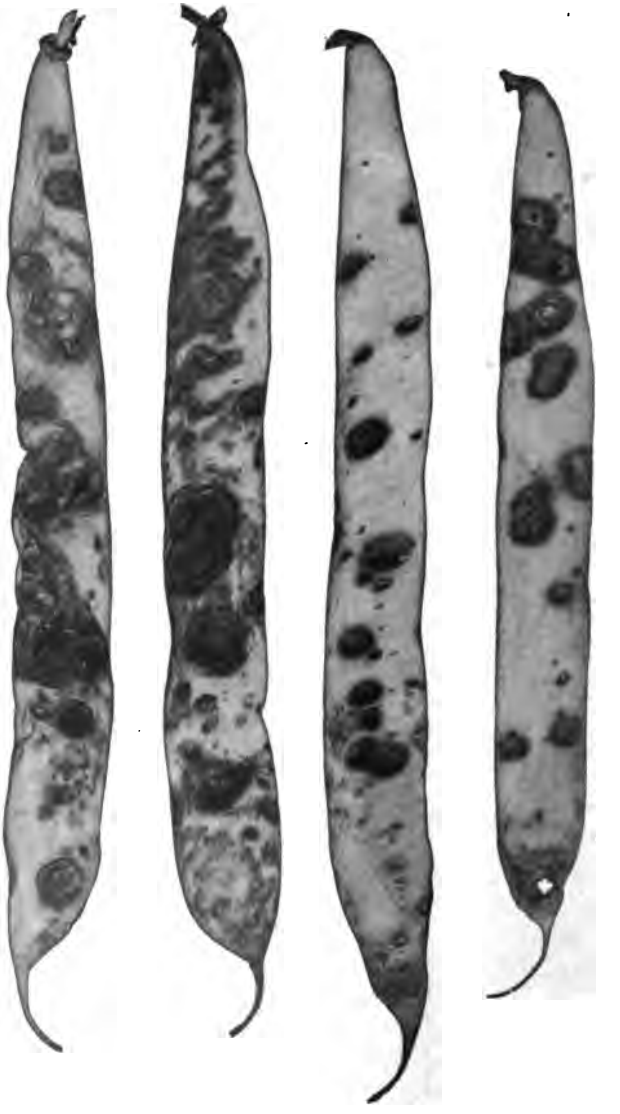

Fig. III.—Bean pods affected with Anthracnose or Pod Spot (After Whetzel. Bulletin 255, Cornell Experiment Station)

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beans affected with anthracnose should never be cultivated while the dew is on them or while they are wet from a shower.

From the affected pods, the disease finds its way to the seed where it produces the familiar rusty-red or brown spots. In severe cases, the whole seed may be involved, altho ordinarily only a slight discoloration is produced on one side.

Bean Rust

Bean rust was observed in several fields last year, but it came so late in the season that little if any damage resulted. The causal fungus, *Uromyces appendiculatus,* attacks the leaves, stems and pods. The rust, as the name implies, can be recognized in its summer stage by the small, raised, rusty-brown powdery specks on the under side of the leaf which rub off easily with the fingers as a rusty-brown powder.

In the winter stage, the specks are black in color and occur on both surfaces of the leaf. When found on the upper side, they are usually surrounded by a light border, apparently where the green leaf tissue has been killed. (See Fig. IV.) While the rust is not uncommon, it has rarely been of sufficient economic importance to cause any considerable alarm. Of course, if the attack should come early in the season and be very general, the crop would suffer in proportion as the vitality of the plant was affected. As the disease winters over on the leaves, the destruction of these by burning offers the best means of eradication.

Bean "Streak"

For want of a better name, the term "Streak" is used here to designate what appears to be a new and undescribed disease of beans, which was observed in Colorado for the first time during the summer of 1916. Whether this is in reality something new, or merely a different manifestation of an old trouble, remains to be seen. It attacks stems, leaves and pods, the symptoms on the first two of these being much the same as with the bacterial blight. On the pods there appear peculiar rusty or orange-brown discolorations in the form of irregular splotches, just as if a brown stain had been spattered on them, and had run down in lines or streaks. (See Fig. V.) The side of the pod next to the plant is practically free from the discoloration, while the outer side may be more or less affected over its entire surface. The leaves are destroyed and the plants become defoliated before the crop matures.

It is our purpose to make a study of this disease during the coming summer and to determine, if possible, its cause and control.

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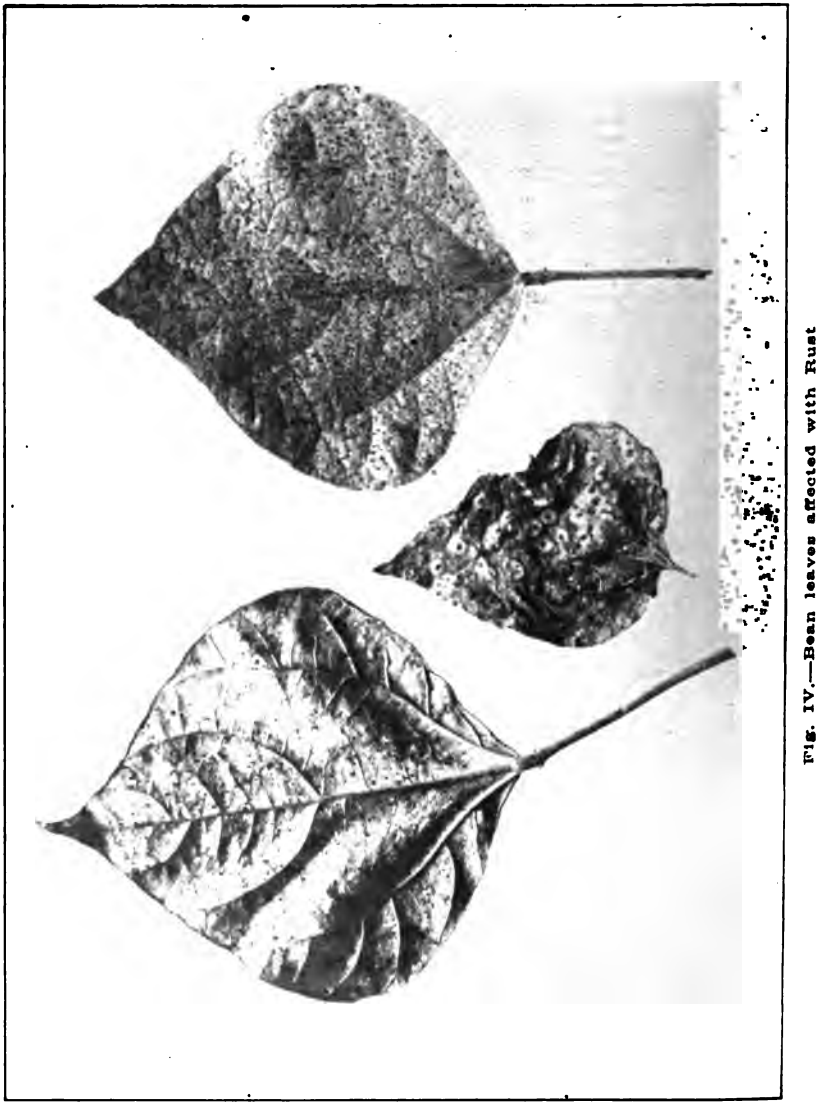

FIG. IV.—Bean leaves affected with Rust

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Fig. V.—Bean pods affected with "Streak"

MEASURES OF CONTROL

The measures of control which can be recommended for any one of the diseases described, apply equally well to all. Accordingly, this phase of the question has not been taken up in connection with the individual diseases, but has been reserved for consideration as a whole.

1. Plant beans on the same land not oftener than once in three or four years, particularly if disease has been prevalent. Soils which once become thoroly infected as a result of continuous cropping are seldom safe to use for the same or closely related crops for years to come.

2. Wherever practical, destroy all diseased vines and trash by burning.

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3. If the bean straw from diseased vines is to be fed, do not use the manure on a field that is to be planted to beans.

4. As far as possible, avoid cultivating the beans early in the morning when there is dew on them, or when they are wet with rain.

5. Hand pick disease-free pods, or if possible, select disease-free plants, for seed. Use these to plant a seed plat on land which has never raised beans and which is removed some distance from the main crop.

Remember that hand picking of seed as it comes from the flail or thrasher for the purpose of controlling disease is of no value, since it is impossible to detect even a small percentage of diseased seed.

6. Seed treatment for beans is of no practical value since any chemical that would penetrate the seed deeply enough to destroy the disease-producing organism would likewise be apt to kill the seed.

7. Spraying with Bordeaux mixture, 5-4-50 formula, even when done thoroly by competent persons, is at best unsatisfactory, unprofitable and only partially successful. However, if one

Fig. VI.—Bean plant affected with "Streak". (By courtesy of Dr. H. G. McMillan.)

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desires to try this, the first application should be made when the plants have their first set of true leaves, repeated ten days later, and again just after blossoming. Remember that if any real benefit is to be derived, the stems, leaves and pods must be kept covered with the spray material.

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Exp. a.

The Agricultural Experiment Station
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Colorado Agricultural College

DRY FARMING IN COLORADO

BY

ALVIN KEZER

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FORT COLLINS, COLORADO
1917

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DRY FARMING IN COLORADO

By ALVIN KEZER

SUMMARY

In dry farming, a crop system adapted to the locality must be adopted. Success depends upon the observance of this rule.

An understanding of the principles of moisture conservation, and of the proper methods of cultivation, is distinctly essential.

Forage crops are best adapted to dry-land conditions.

Cash crops should be raised, but they should be extra enterprises, not the chief dependence.

Rotation is necessary to keep up permanent production.

The crop system should be planned so that the owner can handle the maximum number of acres without hiring help. The more acres the owner can care for unaided, the greater will be his income.

Livestock provides the surest market for dry-land crops.

Excess feed in good crop years should be saved, to tide the stock over lean years, which are sure to come.

There should be a silo on every dry-land farm. It makes it possible to get a maximum of feed value from the crops.

It is highly essential that a new settler have sufficient cash to furnish materials for his farming operations and to pay living expenses for the first year or two. Experience has demonstrated that a dry-land farm does not commence to produce steadily and in a dependable manner until it has been under cultivation a year or more.

A well to furnish water for domestic purposes is an absolute necessity.

A garden, a few chickens and pigs will help make more secure the living of the family.

COLORADO HAS A LARGE AREA OF DRY LAND

Colorado still has a very large acreage of unoccupied and undeveloped lands. Much of these lands lie in regions where irrigation is not feasible; consequently they must be farmed without irrigation, by so-called "dry farming" methods. In order to answer many of the questions raised by settlers and prospective settlers on these lands, this publication has been prepared. It is well known that complete information cannot be given in so short a space, but it is hoped that the essentials of the problem can be handled in such a way that prospective settlers will understand

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the possibilities and difficulties to be met, and some of the means necessary for the successful development of this great unoccupied domain.

What Dry Farming Is.—Dry farming, as commonly understood, means the production of crops without irrigation, in a region where the rainfall lies between the approximate limits of 10 to 20 inches per annum. If the rainfall is much less than 10 inches, the type of farming becomes arid, and when the rainfall lies much above 20 inches, the type of farming followed falls in the class of humid farming.

Successful dry farming depends upon the proper adaptation of crops, the finding of the principles of water movement in the

Swales and bottom lands in dry regions may often be used to produce alfalfa

soil, and an understanding of the principles of moisture conservation and what practical methods of plowing and other cultivation must be followed to get paying results. Most new settlers in Colorado dry-farming sections have attempted to gain success by grain farming. Long experience has shown that a permanent agriculture may be built up in dry-farming sections only where a diversified system of farming is followed. This means a variety of crops, combining cash crops, feed and forage crops, with a properly balanced amount of livestock.

TYPES OF PRECIPITATION

Any discussion of dry farming must consider the time when rain falls, as well as the amount which falls. In different dry-

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farming regions we have at least three types of precipitation—the spring and early summer, the evenly distributed, and the winter season precipitation. In most of the Colorado dry-farming sections, the spring and early summer type of precipitation prevails; that is, the precipitation commences to increase in March and increases month by month until July, when it decreases rapidly for the rest of the year. Such a type of precipitation throws most of the rainfall during the growing season. This type of precipitation prevails thruout the Colorado plains, the region lying east of the Rocky Mountains, and extending to the eastern border of the State. The same type of precipitation prevails in most of the foothills and intermountain dry-farming sections, altho there are localities in the mountains and on the Western Slope where the precipitation largely occurs during the winter season. A different type of dry farming and a different set of farm crops may be grown in regions having the spring and early summer type of rainfall. Here cultivated crops, grains, and diversified farming, are easily possible.

Where the winter type of precipitation prevails, as it does in small areas, the types of crops which may be grown are limited to those which are capable of growing and maturing on the stored water supply of the soil.

COLORADO DRY FARMING REGIONS

The dry-farming regions of Colorado may be easily divided into the "plains", which comprise the area lying east of the mountains, the "foothills", which comprise the valleys and swales in the foothill regions of the mountains, and "intermountain districts".

The plains region is characterized by great extremes of temperature and moisture. The climatic conditions of the foothills and intermountain regions are most equable, but the season is short, due to high altitude. Precipitation is usually, tho not always, greater, but evaporation is nearly always much less than on the plains. Consequently, the plains furnish the most difficult dry-farming problems.

The foothills and intermountain regions present problems largely of precipitation and length of season, while the plains present problems of evaporation, precipitation, violent changes of temperature and violent extremes of wind velocity.

THE PLAINS

Climate and Topography.—Since the plains constitute an area of about twenty-two million acres, possibly three-fourths of the entire possible dry-farming area of Colorado, and since they present most of the problems, the climate and topography of this

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region will be given more attention than that of the foothills and intermountain regions.

The Colorado plains constitute a part of what is known as "The Great Plains Area". They comprise all of that region lying east of the Rocky Mountains from the base of the foothills to the State line. These plains are largely smooth to rolling prairies. The Platte River has cut its valley northeasterly from the city of Denver to the State line. The Arkansas River has made a valley almost directly east and west, just about thru the center of the south half of the plains section. The valley of each of these streams constitutes a depression. Between them lies a more or less flattened ridge of land separating the drainage of the two rivers, known as the Divide, or sometimes better known as the Platte-Arkansas Divide. Many points on the Divide near the foothills reach an altitude of 9,000 feet and even above. Towards the east, the sharpness of slope of the Divide area, and its altitude, decreases until it is relatively flat at the eastern border of the State. These streams and their tributaries cause more or less breaks and rugged features to appear in the otherwise smooth to rolling surface of the plains. These modifications also produce marked changes in soils.

The climate is mild tempered, but subject to very sharp extremes of heat and cold, moisture and dryness. The normal rainfall, according to government and State records, varies from a minimum of close to 8 inches to a maximum of above 18. In years of drouth, the rainfall is decidedly less than the normal. In so-called wet years, rainfall is greatly above. In 1911 the rainfall of the growing season thru the central portion of this region was 7.69 inches. In 1916 it was 7.38 inches. In the years of 1914 and 1915, however, the rainfall was nearly three times this amount, during the growing seasons. These just about mark the extremes of rainfall to be expected, as these four seasons exhibit two of the driest and two of the wettest years since rainfall has been recorded in the State.

The region is a vast plain, unprotected by timber or hills; as a consequence, it is subject, especially during the spring and fall months, to violent winds. A knowledge of these climatic features is necessary in order to arrange proper methods of cropping and soil treatment. The minimum altitude of the section is about 3,500 feet, and the maximum is a little over 10,000 feet; consequently the seasons are relatively short and the nights cool.

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DRY FARMING SOILS

The first essential of success in dry farming is a soil adapted for the production of crops in regions of deficient rainfall. The first essential is that the soil shall be of proper and uniform texture to a considerable depth. The soils best adapted to Colorado dry-farming conditions run from sandy loams to silt loams in texture. No matter what the texture of the soil, however, it must be uniform to a considerable depth. A shallow soil will not hold water enough to carry crops thru periods of prolonged drouth. A layered or stratified soil gives rise to a different series of water relations, which prevent the crops from getting and taking out the watter supply in the soil, except during wet years. Gravels, heavy clays and adobes are very poorly adapted for dry farming. A shallow soil overlying gravel, rock, shale, or clay, will only produce crops in wet years.

For the most part, the soils of Colorado dry-farming regions are deep and rich. They are rich because they have been formed in an arid or semi-arid climate, consequently the mineral elements of fertility have not been leached out. Most of these soils are deficient in organic matter (vegetable matter). For the most part, they are rather light in nature, sandy loams and silt loams being much more numerous than adobes and clays. In some localities there are areas of gravel; in a few, there are areas of almost pure sand. Such areas are often wind blown into sand dunes or sand hills. A few regions have soils of almost pure silt. These regions are characterized by soils of great depth, very desirable water relations and great certainty of productivity, rainfall considered. Only a few soils surveys have been made. These have been made by the United States Bureau of Soils in Larimer and Weld Counties, in the Arkansas Valley, in the San Luis Valley and in the Grand Valley.

Owing to the prevalence and tendency of high winds, methods to prevent soils blowing must often be devised and practiced. Control methods consist largely in keeping the immediate soil surface rough on all cultivated land which is in crop. Anything which will break the force of the wind at the soil's surface is effective. Over much of the plains area fall plowing is inadvisable because of the tendency and danger of soil blowing. In such sections, fall listing may be successfully practiced, making furrows crosswise of the direction of prevailing winds. Soil listing not only conserves moisture, but it prevents blowing, keeps down weed growth and leaves the soil in good shape for catching any winter precipitation.

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Listed to prevent soil blowing and for summer fallow. This system has been practiced for fifteen years on this farm. During this period this farm has not had a complete crop failure

In the spring, a seed bed may be prepared by breaking out the middles and leveling down the land with disk and harrow, or, in many instances simply by leveling down the land with disk and harrow. Where soils have a tendency to blow during the summer season, the tendency can be largely overcome by planting crops in strips so that strips of corn or sorghums are interspersed with strips of grain. These methods will almost entirely prevent soil blowing except in sand-hill sections where the soils are almost pure sand.

SOME PRINCIPLES OF SOIL MOISTURE FOR DRY FARMING

Dry farming never means farming without moisture. But it always means farming where the supply of natural moisture is deficient or low. Consequently, any discussion of dry farming that does not take into consideration the principles and conditions under which moisture is obtained, conserved and used, fails to meet all of the problem.

In saving soil moisture, the first and most important process is to get it into the soil. If a rain of 3 inches falls and only 1 inch penetrates the soil, the land is worse off than if it had a 1-inch rain, all of it entering the soil. The 2 inches of water which did not soak in, ran off the top, carrying with it some soil, beating and puddling the surface, thus favoring the formation of a soil crust. Consequently, all cultivated land should be kept in the best possible condition to catch rainfall.

What is that condition? Moist soil takes water rapidly, while dry soil takes water slowly. The first effort then should be to

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keep the soil always moist. This may be illustrated by experiments made during the summer of 1907. The summer was wet early, but dry from July on until September 28th. In the experiment the stubble of grain fields was given this treatment. One field was disked behind the binder. As soon as the grain could be taken off, the field was plowed. Each half day of plowing was disked and harrowed. The plowing was done in July. A second field was not touched after harvest until the first of September. No treatment was given after plowing. The soil of the first field was in fair tilth. The soil of the second field was in poor tilth, being very dry, lumpy and cloddy. Rains came September 28th and 29th and October 3d and 4th. In all, a fraction over 4 inches of water fell in the period. Field No. 1 was in fairly good condition before the rains. The 4 inches of rain wet the soil in this field so the surface moisture went down slightly over 2 feet. In field No. 2 the same rain only went down about 8 inches. Thus, field No. 1 was in very excellent condition for fall seeding, while field No. 2 was too dry to justify fall seeding in spite of 4 inches of rain. In other words, in field No. 2, 4 inches of rain had only been sufficient to put the soil in shape to catch future rains.

The time of breaking is very important. Plowing should be done in the spring or early summer for fall crops, and in the summer and fall for spring crops. Where there is danger of soil blowing, listing or middle breaking may be used in place of plowing.

Water moves very much faster in a moist soil than in a dry one. Very dry soils actually repel water at first. It might be asked, how is it possible to keep a soil moist? Never let it get dry. Keeping soil from becoming dry requires careful methods of cultivation and cropping.

Surface Treatment to Catch Rainfall.—What kind of treatment the surface soils shall be given to assist in catching rainfall or snowfall depends upon the kind of soil—whether sandy, silt or clay—upon the kind and time of plowing, whether the plowing is on breaking or old land, and upon the kind of crop grown.

Sandy lands are open and porous. They take rainfall readily. Such lands may be plowed relatively shallow, because they will take rain practically as fast as it falls. Silty and clayey soils are less open. Under natural conditions such soils will not take rain as fast as it falls, unless the rain is a drizzle. To make such heavy, close-textured soils take water as fast as it falls in normal rains, it is necessary to plow very deeply. Deep plowing makes a rough layer which takes in rainfall rapidly. This loose layer

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forms a temporary reservoir, holding the water for a time and then passing it on slowly to the more tight subsoil.

Kind of Plowing for New or Old Land.—Plowing on old lands should be as deep as possible. If the plowing is done long enough before seeding to permit nature to do the settling and compacting, it can scarcely be too deep on silt and clay lands. If, however, breaking cannot be done a considerable period before seeding, it should be relatively shallow, because usually it cannot be properly settled and compacted immediately prior to seeding. The disk following the plow will be of service. But it does not equal time and rainfall. Besides, plowing breaks the existing moisture relations and time is essential for readjustment. Unless followed by rain, deep plowing immediately before seeding will give poorer yields than shallow plowing.

Movement of Water in Soil.—After the water is caught by the soil, it undergoes certain movements. When it moves downward thru the spaces between the soil particles by its own weight, we say it percolates. When it crawls upward or downward or sidewise like water in a lump of sugar, or oil in a lamp wick, we say it is capillary or film movement, because it moves along as a thin film over the surface of the soil particles. Sometimes changes in temperature cause soil water to move. In that case we say there is temperature movement or thermal movement.

Water is held in two ways in the soil, as a film which surrounds the soil particles and in the tiny spaces between soil particles. When it rains, water enters the soil. When the surface gets more water than it can hold, it loses some by percolation to the soil below. That is, some of the free water flows from the soil spaces above to the soil spaces below. This process continues as long as it rains and often for a time afterwards, depending on the amount of rain.

When percolation ceases, another movement begins. The films begin to crawl from particle to particle as water in a lump of sugar, only much slower. Very dry soils wet very slowly, but when the particles are very slightly moistened, they tend to draw water from the moister towards the drier soil particles. This movement continues until the pull away is balanced by the pull to hold.

Most deep soils in regions of moderate or slight rainfall never have their subsoils thoroly wet. In fact, they are rarely ever moistened beyond the depth of a few feet. The rains wet the surface. A portion of the water percolates a little further in. After percolation ceases, the water penetrates a little further by film movement. In such deep soils free water moving in the soil

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spaces does not exist for any length of time. The water is all held as thin films around soil particles. These are stretched as thin as they can be by soil attraction, because there is always dry soil below trying to pull it away from the moister soil above. The condition is a balanced one, one portion of the soil trying to pull the water away and the other resisting with equal strength. This condition we call the minimum capillary or film capacity. In a sandy soil this minimum film capacity varies somewhat, but is from 7 percent to 11 percent. This percentage of water ranges from 0.84 inch to 1.32 inch per foot of soil. In a silty soil the percentage is higher, ranging around 12 percent to 18 percent, depending on the proportion of silt in the soil. This equals from

In dry years, Russian Thistles may help out the feed supply, if harvested at the proper time

1.44 inches to 2.16 inches of water per foot of soil. In a clay or adobe soil the percentage of minimum film water amounts to 18 to 25 percent and even more where the percentage of clay or adobe is very high in the soil. The percentages equal from 2.16 inches to 3 inches of water per foot of soil. Thus it is seen that heavy soils, as silt and clay, retain more water per foot than light sandy soils.

Available Water.—But all the water a soil contains is not available for the growth of plants. Plants can only take out a portion. Some plants can take out more than others. For instance, sorghum will dry out a soil more than wheat. Wheat will take away more water than corn. Russian thistles and sunflowers will dry out a soil worse than any of those crops which we try to grow for profit. Most crops will dry out a sandy soil so that only 2 to 4 percent of the moisture remains.

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From the minimum capillary capacity, we see that a sandy soil would have from 5 to 7 percent of available water, amounting to 0.6 inch to 0.84 inch per foot. A silty soil would be dried under similar conditions to 7 to 12 percent, depending upon the physical composition of the soil, giving from 5 to 9 percent of available water amounting to from 0.6 to 1.08 inch of water per foot of soil. A clay soil under similar conditions would retain from 12 to 18 percent, depending upon composition, leaving available from 6 to 7 per cent or slightly more, equivalent to from 0.72 inch to about 1 inch of water per foot of soil. While there are great variations in individual soils, it is seen that, under dry land conditions, the available water is nearly the same in widely different soil types.

Amount of Water It Takes to Grow Crops.—Investigators in dry-land crops agree pretty well that it takes from 300 to 400 and up to as high as 1,000 pounds of water to produce a pound of dry matter in the crop. That is, the crop uses up that much water in growing a pound of dry matter.

Thus a sandy soil which contained from 0.6 to 0.8 inch of available water per foot would have to contain this amount of available water 5 to 7 feet in depth to grow a 15-bushel crop of wheat from the soil water unless helped out by rain. The same principle holds with other soils and other crops altho the limits are somewhat different for each soil and crop. This principle is: A dry-land soil must be deep in order to hold enough water to insure crops. Crops will dry out a shallow soil quickly. Then, if no rains come, the crop dies.

The dry-farming soil must be of uniform texture, also; a layer of gravel or gypsum below the surface will cut off the effective depth of soil. This was very well shown in the season of 1911 at Rocky Ford. In a field of alfalfa two spots were noticed where the crop was not growing. Borings revealed a gravel layer under one spot and a gypsum layer under the other spot. These layers of different texture broke the continuity of the soil mass and prevented the roots getting water at lower depths.

Under normal dry-farming conditions, there is very little movement of the soil moisture except after rains. The soil water does not move to the plant roots. The roots move to the moisture. If one will take a dish of wet soil and sprinkle dry soil on top, water will move up into the dry soil. If this is then scraped off and dry soil again sprinkled on top and scraped off when moistened, a point will soon be reached when the dry soil will no longer be moistened. We will then have a condition comparable to dry-farming soils (except immediately after rains). This is

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the minimum capillary or film condition already mentioned. In such condition the soil water does not move unless more water is added or the temperature changes so as to alter the soil water relation.

Loss of Water by Evaporation.—Experiments were made in California to determine the water loss by evaporation. The experiments were run from June to September. The average evaporation from a free water surface was about 2.88 inches per week. The evaporation from a saturated soil surface was 4.88 inches per week. When the moisture in the surface soil was about 11 percent the evaporation was less than 1 inch per week. When the percentage of water in the surface soil was slightly above 4 per cent the loss by evaporation was less than 0.25 inch per week. In other words, a dry surface soil prevents surface evaporation.

Most dry land soils do not lose their moisture by evaporation. The moisture is lost by plants which use up the soil water in growing. In order to conserve soil water, plants must be kept from growing while it is being conserved.

Advantage has been taken of the soil properties which have just been mentioned to store up the water falling one season to be used the next, by summer tillage or summer fallowing. If the land is cultivated one season to keep down weeds, to keep a dry surface and to put the soil in better shape to catch rainfall, a large part of the precipitation of the season can be caught and saved to be used the next season. Just how much can be caught and saved depends on how the precipitation comes. When the precipitation falls in quarter-inch or half-inch rains, very little can be saved because most of it will be lost when the dry surface is produced. Very heavy, dashing rains run off faster than they can soak in, even when the soil is in the best of shape to take in moisture. More water can be saved from a heavy slow rain or drizzle than from any other kind of precipitation. On the average, on good normal soils, it will be possible to store from 50 to 70 percent of a season's rain to be used the next. Thus, if the normal rainfall is 15 inches, the clean summer fallow will make from 20 inches to 22 or 23 inches of water available for the use of the growing crop, as a portion of the rainfall of the previous season is stored for use in the present season. The clean summer fallow greatly increases the certainty of getting crops.

It has been found by experiment, and proved by experience on many farms, that it is possible to get practically all the benefits of a clean summer fallow and at the same time raise some crop on the land. The crop, of course, must be a cultivated crop. Pinto beans, corn, grain or forage sorghums may be used as a crop. When

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they are used to accomplish the objects of a clean summer fallow, about half the usual number of rows of corn are put on the land. The method may be illustrated by using corn. Corn is ordinarily planted in rows 3½ feet apart. Where it is desirable to grow corn, and still get part of the benefits of a clean summer fallow, the corn is planted in rows 7 feet apart. The space between the rows is kept cultivated so as to keep down all weeds. About three-fourths as much crop may be grown by this method of tillage as by the thicker planting. Crops such as wheat and other small grains after corn grown in this way do just as well as after clean summer fallow. This method has a very decided advantage over the clean fallow in that a paying crop may be grown. Thus the work of keeping the land clear by this method is paid for by the crops grown, while the clean summer fallow method produces no return the year of the fallow.

The farming methods which will enable the most crops to be produced, and make the best out of the available water with the least amount of work, are to be preferred. Many successful dry-land farmers, especially on the lighter lands, follow a system which reduces the amount of plowing and still conserves moisture and prevents weed growth. For these lighter lands the suggested system is about as follows: The system makes use of a partial summer fallow. If we start a description of the system at the point where the land has been partially summer tilled, we may carry the process thru its logical steps. After the partial summer tillage, winter wheat is the first crop. When the winter wheat is harvested, the land is double disked immediately after the binder for the purpose of killing all weeds which spring up and to put the surface in good condition to catch rainfall. The next spring the land is double disked early to kill all weeds starting. If weeds start later, it is disked again and harrowed; after which, corn or some other cultivated crop is planted. After corn, small grain of some kind is planted, the soil being prepared by disking and harrowing. The yields of grains after corn are nearly as much as after a fallow. When this latter small grain crop is harvested, the land is at once double disked. No other treatment is given until the next spring. Then, as soon as weeds start, the soil is disked to kill weeds, and the better to catch rainfall. In June and July the land is plowed thoroly and deeply. It is disked and harrowed immediately behind the plow. Upon this plowed land, so prepared, winter wheat is planted in September, and the system starts in again where we began.

Under this system the land is plowed only once in every three years. The system produces excellent results on the lighter lands,

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reduces the danger of soil blowing and can be carried out very much more cheaply. Some of the heavier lands, such as the clays and adobes, require more frequent plowing. On such lands the loss ordinarily caused by the summer fallow can largely be overcome by planting a cultivated crop and spacing rows double the usual distance.

It must be remembered that the supply of water in all dry-farming sections is limited or likely to be limited; consequently, if more crop is planted on the land than the soil is capable of supplying with water, yields will be reduced. Thus the stands of crops, to produce best yields under dry farming, must be much thinner than is required in humid or irrigated regions. If too many plants are on the land, none will get enough water and all will fail. The best success is obtained with relatively thin stands. It is impossible to give the exact amount of seed which should be planted for dry-farming conditions, because the amount varies widely according to the severity of the climatic conditions, the type of soil and the total precipitation.

The following list, however, can be taken as a general guide and is suggestive of the practice which should be followed, namely, to make the stand of grain proper for the conditions of soil moisture:

AMOUNT OF SEED TO USE FOR THICKNESS OF STAND FOR DIFFERENT CROPS UNDER DRY FARMING

Wheat, 20 to 35 pounds.

Oats, 40 to 60 pounds.

Barley, 40 to 60 pounds.

Rye, 30 to 40 pounds.

Corn, stand for ordinary cropping, rows 3½ ft. apart, stand in the row, 20 to 24 inches, drilled.

Corn to be used on land in place of summer fallow, rows 7 ft. apart, stand in row, 20 to 24 inches, drilled.

Cane, for seed, broadcasted, 15 to 20 pounds.

Cane, for seed, drilled, 6 to 15 pounds.

Cane, for hay, broadcasted, 30 to 40 pounds.

Kafir, for hay, in rows 3½ ft. apart, 2 to 4 inches in the row.

Milo, for seed, in rows 3½ ft. apart, 4 to 8 inches in the row.

Kafir, for seed, in rows 3½ ft. apart, 6 to 12 inches in the row.

(Kafir and milo will require from 3 to 10 pounds of seed per acre, depending on the thickness of the planting.)

Feterita, for seed, in rows 3½ ft. apart, 8 to 12 inches in the row.

Flax, 20 to 30 pounds per acre.

Millet, 15 to 30 pounds per acre, depending on conditions.

Alfalfa, broadcasted, 3 to 5 pounds per acre. In rows 3 to 3½ ft. apart, 2 pounds per acre. If the seed is good and proper tools for drilling are available, half a pound of seed per acre will make the stand thick enough.

Potatoes, in rows 3½ ft. apart, 1 to 2 ft. in the row, 300 to 400 pounds seed per acre.

Pinto beans, in rows 3 to 3½ ft. apart, 6 to 10 inches in the row, approximately 15 pounds of seed per acre.

Field peas, preferably in rows and cultivated, 20 to 30 pounds per acre.

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GENERAL FARMING PRACTICE AND MANAGEMENT

Dry farming at its best is serious business. As a consequence, there are certain fundamental considerations which the settler should bear in mind. A well for domestic water supply is absolutely essential. If such domestic water supply cannot be obtained upon the land or immediately adjacent to it, other features would have to be extremely desirable to make it advisable to locate a home there. The production of crops is more or less uncertain and the prospective settler should by all means bring sufficient capital in money, or in money and materials, to carry him thru at least one year until production can be started.

For the most part the plains are treeless. In the building of a home, one of the first things, after the house and sheds for livestock are provided, should be the making of some provision for trees. Where land is properly prepared and properly cultivated, trees can be grown almost anywhere on the plains, providing they are given sufficient space. The moisture supply on dry-land soils is always less abundant than it is in the humid regions; consequently, the trees should be set much farther apart. The sod should be broken up at once in preparation for planting trees. A strip should be plowed at least 20 feet wider than the expected space which the trees will occupy. This should be kept free of

Thrashing "smutty" wheat, a source of heavy loss to many wheat growers. Seed treatment, costing from 8 to 15 cents per acre, will prevent smut

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weeds by plowing or other form of cultivation to permit the accumulation of water. Sometimes the soil can be sufficiently moistened, when such clean cultivation is followed, in one season to permit perfect safety in tree planting. Sometimes two seasons must elapse, and in extreme seasons as many as three. The ground should be ready and have sufficient moisture before trees are put out.

The planting of trees will make it possible to have some shade about the home. In addition to this, trees will break the dreary monotony of the plains, a monotony which is very real to all those not born and bred plainsmen. The women folks of the family are especially susceptible to this loneliness because of the isolation and difficulty of social relations with the neighbors.

The dry farmer should make provision for a garden somewhere near his well. If a good well is present for domestic water supply, it can be used, especially if a little storage is possible, to insure a good small garden if the water is properly applied at the right time.

The dry farmer should by all means plan his cropping system so as to grow feed for at least a few chickens and pigs, so that the family living will be insured. The type of other livestock which he chooses to grow will depend a good deal upon his location, as either dairy or meat animals can be made profitable. There will be seasons when an abundance of feed will be produced. There will be other seasons when the amount of feed produced must be very carefully husbanded in order to permit existence; consequently, sooner or later the dry farmer should come to the proposition of saving all of his feed, and in extra good crop years to store up excess feed to tide him over the lean years which are bound to follow one season or another.

The wide use of the silo is sure to come as a part of this development, because it permits all, or practically all, the feed grown to be stored in available succulent condition for future feeding. In 1912 the Experimental Substation at Cheyenne Wells produced feed enough to have carried the herd on the land at that time for a period of two years. The silo capacity was limited to two pit silos at that time. They were filled to capacity, but they were only capable of carrying the herd thru the winter and the following early summer. In 1913 by saving every bit of feed that it was possible to save, and putting it into the silo, it was not possible to quite fill even these two silos. In 1914 two more silos were put down so that now we have capacity enough to carry the normal regular herd thru a period of two years if extreme conditions should appear.

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No method of dry curing of the crop is so efficient that it does not waste at least as much as 30 per cent. In the dry, windy conditions which prevail, as much as 80 percent of the feed value may be lost. If put in the silo, at least 90 percent should be saved, under normal conditions. In other words, the loss need not be over 10 percent and often will be less than 5 percent. The silo making possible this great saving in feed is bound to have a much greater use upon the dry farms.

Removing silage from pit silo, the type of silo best adapted to dry-land regions

In many places dry farmers are making use of open range available to carry their stock in the summer. During some seasons this open range will be cut short by extreme drouth so that the animals lose flesh or fall off in milk production according to the kind of animals kept. If the dry farmer had a silo at this time, he could open the silo and feed some silage during the period of short pasture and keep up his gains on beef animals and his milk production on dairy animals.

The entire question of dry farming and its success, then, can be summarized in the following brief statement of conditions: Forage crops are best adapted to the soil and climatic conditions. Under the best management, they should be grown and placed in the silo and be fed later to livestock. The livestock will constitute a constant market for successful crops which have no other available market. Cash crops should be grown, but they should be put on as an extra, or extra enterprises, rather than the chief dependence of the dry farmer. In most seasons some saleable

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crop will be available from these so-called cash crops. Such income will be a welcome addition to that brought in by livestock. Of the cash crops which may be grown, winter wheat, pinto beans, flax in some of the northeastern sections of Colorado, broom corn in many sections, and some of the grain sorghums in the southeastern part of the State, will constitute the larger portion possible. In a few localities, corn may be successfully used as a cash crop, tho in most sections it will make the greatest returns harvested entire and siloed.

SOME SPECIAL FEATURES OF MANAGEMENT INFLUENCING THE SUCCESS OF DRY FARMING

During the past few seasons, the Experiment Station has been making studies of a number of dry farms in five counties in the dry-farming district of Colorado. These studies have had several objects in view, primarily, however, they hope to discover the fundamental principles of success in the organization of the farming business under dry-land conditions. Already these studies have resulted in much valuable information being obtained. We have long known that one of the causes of failure on dry lands was the lack of sufficient means or capital to survive the first year or two of development. These studies have further shown that the profit of the farming business under dry-land conditions increases with the amount of capital invested. We have a way of measuring the profitableness of the business, that is, by a study of the labor incomes. The labor income is considered as the net farm income, less interest on the capital invested in real estate and working equipment. In other words, labor income is that income which the labor earns whether that labor is physical or managerial.

On dry farms in Eastern Colorado the labor income has increased uniformly with the increases in capital up until the capital reached about $20,000. In other words, the greatest returns from the labor used on dry-land farms in Colorado has been obtained where the capital in the shape of real estate and equipment amounted to about $20,000.

But the amount of capital used is not the only thing which influenced the size of the labor income. Uniformly, in the five counties studied, the labor incomes increased as the number of acres in crops increased and the labor income increased uniformly as the number of acres in crops tended by one man increased. In other words, the man who could so conduct his business as to handle more acres, either by a better system of working, or by

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diversifying his crops so as to distribute the work thru longer periods, was rewarded by a higher labor income.

In those counties where dairy stock was kept, the labor income was almost in exact proportion to the receipts from dairy products. Dairy stock has uniformly been more profitable than beef stock, as the following comparison, taken from El Paso County, will show. The illustration is typical of other counties:

One way of utilizing many dry-land crops

On fourteen farms the average receipts per year per cattle unit (a cattle unit is a full grown animal or its equivalent in young stock) was $44, and the average feed cost per animal unit was $28, or an average net return of $16 per animal unit. On fourteen farms in the same locality beef cattle returned an average of $28 per cattle unit, while the feed cost per animal unit in the case of the beef animals was $21, leaving a margin of $7. On the dairy cattle farms, 94 percent of all live stock was dairy cattle. On the beef cattle farms 96 percent of all live stock was beef cattle. Dairy cattle adapt themselves much better to a small business than beef cattle. In a large business both may be successfully used. If properly managed, both are capable of profit.

A thoro study of these investigations brings out the further fact that the proper proportion of live stock to crop acres must be maintained to get the largest profits. On the average, this has been found to be about eight crop acres per animal unit. The average crop value per acre in the five counties studied was about $12.30. It is not yet possible to give average costs for producing this average crop value. But it is possible to give the amount of

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work normally required. The item of work covers everything except interest or rentals, depreciation and similar items of cost. Labor costs differently in different neighborhoods, so that it is at present almost impossible to place a fair average value for the labor expended. Accordingly there are listed below figures which show the number of hours of man labor and the average number of hours of horse labor required to produce a few standard crops.

The following table gives several crops, the number of acres of each kind of crop used, and the amount of labor required per acre per year for the production:

Kind of crop	No. of acres studied for each crop	No. of man hours per acre per year	No. of horse hours per acre per year
Corn	13,000	15	42
Spring Wheat	470	12	26
Winter Wheat	370	10	23
Oats	1,200	15	28
Barley	140	10	28
Rye	180	12	23

Oftentimes, by taking advantage of good management principles, the same amount of labor can be made to accomplish a greater amount of work. For instance, the farmer who arranges his cropping in a rotation system so as to require plowing only once in three years, and still keeps up his production and soil fertility, will produce his crops with much less labor than the man whose system requires him to plow all of his tilled land each season. It has been shown above that the labor income was increased when the crop acres tended by one man was increased. To increase the crop acres per man requires some extra equipment, usually, but more often a better arrangement of work and farming system. The largest labor incomes have not been produced on farms getting the highest yields. They have been produced, however, on those farms getting just about or a little above the average yield. Extra high yields are usually produced too expensively to return a profit. The law which economists call the law of diminishing returns comes into play. Briefly stated, this law is: Extra work or capital applied to an enterprise sooner or later reaches a point beyond which the addition of capital or labor produces increases in product at greatly increased expense.

The most profitable businesses on the dry lands have been those which had considerable diversity—at least from three to five sources of income. These different sources of income can be kept up by the growth of live stock, forage crops and cash crops.

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CROPS FOR DRY FARMING

In considering crops for dry-land agriculture, it must always be remembered that a rotation is necessary to keep up permanent production on the land. In any rotation, legumes must be used sooner or later. The available and profitable legumes are limited. They consist principally of alfalfa, sweet clover, field peas and pinto beans. Legumes are just as necessary to help balance up the feed ration as they are to assist in maintaining soil productivity. The crops which are most certain and are easiest to grow make rather starchy feeds. Some legume to mix with such feeds is highly desirable.

ALFALFA

Alfalfa can be grown in many localities if the land is properly prepared and the crop properly cared for. Alfalfa may be grown for forage if planted in rows from 3 to 3½ feet apart. When so planted, alfalfa should be cultivated to keep down weeds. Only a few cultivations are necessary if they are done at the right time. If drilled or seeded broadcast, alfalfa should be seeded thinly. Three pounds of good seed is amply sufficient if the soil is properly prepared. When well cared for, alfalfa should produce from three-fourths to 1 ton of cured hay per acre per year. Since this alfalfa hay is worth pound for pound as much as bran to feed with the common feeds of dry-land sections, it

Alfalfa in rows for seed production or increased hay production under dry conditions

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really has a greater value to the dry farmer than the average price of alfalfa hay would indicate.

Varieties.—Experimental work has shown that the best varieties to grow on the dry lands are the Baltic and Grimm. The Baltic and Grimm are very much alike. In fact the Baltic is a selection from the Grimm. These two sorts are superior for both hay and seed production.

Preparation of the Seed Bed.—Alfalfa will probably occupy the land for a number of years, so every possible precaution should be taken to get it started right. In order to do this a properly prepared seed bed must be provided. The seed bed should be moist to at least 2 feet in depth in order to insure sufficient water to germinate the seed and keep the young plants growing for a considerable period. Of course, rains may come and render all of these preparations unnecessary, but it should be understood that rains sometimes fail to come for a period of three months. If the seed bed has been properly prepared, the young crop will stand this long a period of drouth. In preparing such a seed bed, it is often necessary to follow complete or partial summer tillage. Alfalfa does best on land which has been plowed and afterwards well packed. The surface should be granular rather than fine and dusty. The granular or "small cloddy" surface takes up moisture better than a dusty surface, and blows less easily. Usually the best time to plant will be from May to July; more often May is the preferable month.

SWEET CLOVER

In Colorado, sweet clover has been considered a serious pest until very recently. Now many are coming to recognize the value of this crop. As a soil renovator there is no legume that will give as quick and desirable results as sweet clover. When cut at the proper time it makes very nutritious hay and produces a very fair yield. In many places where alfalfa is difficult to start, sweet clover will do well. It is sufficiently valuable to be given a thoro trial in many dry-land sections.

Varieties.—There are three varieties of sweet clover which may be encountered. The white sweet clover, the yellow sweet clover and the small annual sweet clover. The two first named varieties are biennial, that is, the plants live two years. The annual yellow sweet clover is not agriculturally valuable in any of our territory. In most sections white sweet clover is preferable. In regions where the altitude is from 7,000 feet upward, yellow sweet clover is to be preferred over the white.

Soil Preparation.—The soil for sweet clover should be prepared exactly as for alfalfa.

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Seeding.—Sweet clover may be seeded in the spring or fall. Where it is not in danger of being blown out in the winter time, fall seeding may be used. When seeded in the spring it should be seeded as early as possible to get it in the ground.

When cut for hay, the first cutting should not be made until the sprouts which shall produce the second crop begin to appear. Usually one crop may be cut the first year. The second year two cuttings should be received, except in years of extreme drouth. In cutting the second year's crop, the cutter bar on the mower should be set high, in order not to kill the plants. The plants start from sprouts which come out on the stalks close to the ground. If cut below these sprouts, the crop will be killed. High cutting obviates this danger.

FIELD PEAS

Field peas, or Canada peas, are exceedingly well adapted for the dry farms in altitudes of from 6,500 to 8,500 feet. They are not so well adapted in the lower and warmer sections. It is possible to grow them but usually they will not pay a profit. They should be seeded on well prepared land at the rate of about 20 to 30 pounds per acre, preferably using a disk drill with a revolving cup type of feed so as not to crush the seed. Peas grow best in cool regions. It is for this reason that they are better adapted for the higher altitudes.

PINTO BEANS

The so-called pinto beans are one of the Mexican varieties. This variety is most commonly grown, is one of the very best yielders, is well adapted for dry-farming sections below 7,000 feet in altitude, and has an established market. The average yield of these beans under dry-farming conditions has been from 300 to 800 pounds per acre. Many growers have obtained much higher yields. These beans sell on the market from as low as 2 to as high as 6½ and 7 cents per pound, depending upon the market demand. They, therefore, constitute a very excellent and certain source of cash income. The straw will yield from one-half to three-fourths of a ton and sometimes more, per acre. The straw, when fed with silage, is worth as much as alfalfa hay. In addition, beans are legumes and assist somewhat in keeping up soil productivity when they are used in rotation.

Preparation of the Soil.—Pinto beans should be planted on flat, prepared land in rows 3 to 3½ feet apart and in drills in the rows. The amount of seed for dry-land conditions will vary from 8 to 18 lbs. Fifteen pounds may be put as a fair general average, where growing conditions are favorable.

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Cultivation should be shallow, as beans are a surface-rooted crop. Cultivation, while shallow, should be frequent enough and thoro enough to prevent the formation of a crust on the soil and to keep down weed growth. Great care must be exercised not to cultivate when the vines are wet. At such a time the vines are easily broken and the danger of being infected with some of the common bean diseases is greatly increased. Beans are harvested by means of a bean harvester. Many of the modern forms of harvester have a bunching attachment which materially decreases the labor of bunching. Pinto beans should be harvested before they are completely ripe, because they will ripen in the shock or bunch and, by harvesting in this way, danger of shattering is almost eliminated.

Increased prices may be obtained by thoro machine-cleaning and uniform bagging of the product. Pinto beans should not usually be planted more than one year on the same patch of land because of the danger of bean diseases. In order to reduce the danger of disease still further and to increase the yield, it pays to hand-select the seed from high-yielding plants which ripen early and uniformly.

CORN

Corn is one of the most important grain and forage crops. In many sections no forage will produce as high yields per acre. In the higher and moister sections, on the Arkansas-Platte Divide region, corn will produce a greater tonnage than any other similar forage. There are many other localities where it will out-yield the grain or forage sorghums. Where corn will out-yield such other crops it should be used for forage. It makes an excellent fodder where properly cured and when stored in the silo makes the very best silage possible. Corn can be grown in cooler localities than can any of the sorghums. It is probable, therefore, that corn will take the first place in the cooler and moister sections, while the sorghums will take first place in the drier and hotter sections of our territory.

Preparation of the Soil.—The best method of soil preparation for corn depends upon the character of the soil, the rotation, and the crop which precedes corn on the land. If the land is rather light and sandy, fall plowing is not wise on account of danger of soil blowing. However, such lands may usually be managed so as to keep down weeds and put the surface in shape for catching winter and spring moisture. Where small grain or an early harvested cultivated crop preceded corn, the land may be double disked at once to kill weeds and put the surface in good condition for catching rainfall. The ... of plowing, the land is

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listed. Experiment shows that this practice stops danger of blowing. In the spring, just as early as possible, the middles are broken out.

Listing tends to lengthen the time required to develop corn to full maturity, consequently, planting corn on listed land is not always advisable. Where, on account of the difficulty of maturing listed corn, it is advisable to surface plant, the listed ground is worked down by disking and harrowing.

Often on the lighter lands, experiment has shown that a system may be followed which keeps down weeds and conserves moisture at a great reduction of labor without reducing yields. Thus the cost of production is kept down. The suggested system is carried out as follows: Starting the system and rotation with summer tilled land, the first crop put on is winter wheat. Immediately after the binder, the land is double disked for the double purpose of killing all weeds which spring up and to put the surface in good condition to catch rainfall. The following spring the land is double disked early, then corn or other cultivated crop is planted. Following corn, small grain is planted. The yields of grain after corn or other clean cultivated crop are nearly as large as after the fallow. After this last small grain crop is cut, the land is double disked. It is then allowed to lie. The following spring, as soon as weeds start, the soil is again disked to kill weeds, preserve tilth and the better to catch rainfall. In June and July the land is plowed thoroly and deeply, disked and harrowed immediately behind the plow. Winter wheat is planted in September and the rotation is under way again. Such management has been found more successful on many soils than more frequent plowing and the cost of following the system is very low.

Upon the soils which give better results from plowing each season, the soil should preferably be plowed early in the fall, the earlier the better.

Time for Planting.—Over most of the plains area, corn can be planted by the 10th of May. In the extreme southeastern part of the Colorado plains, planting can be done the last of April or the first of May. In the extreme eastern part, some planting may be done by the first of May, but usually it is not wise to put in corn very much before May 10th. Nearly always the plains are subjected to a frost about the middle of May and there is little use of getting corn in prior to this danger period for frosts. By this time the ground has become somewhat warmed so that the crop will start off readily.

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How to Plant.—Corn should be planted in rows 3½ feet apart. If drilled on the dry land there should be one seed about every 18 to 22 inches. If checkrowed, only two kernels to the hill should be planted.

In very dry localities where experience shows difficulty of getting sufficient moisture to produce a crop, the rows may be planted 7 feet apart, or double the usual distance. When thoroly cultivated, such wide planting insures a crop in years when ordinary planting fails. With such wide planting, the seed may be put in a little thicker, 15 to 18 inches, in the row when drilled. This method of planting has been tried with success in several Colorado plains localities.

Varieties.—There are an infinite number of corn varieties, but owing to the altitude and the shortness of the season, only the short season or so-called northern corns should be planted. Of the native varieties which have been tried out, the Swadley Dent, the White Australian Flint, and Parson's High Altitude corn have given very excellent results. For the more northern portions of the Colorado plains area, Pride of the North, Minnesota No. 13, Minnesota No. 23, and Wisconsin No. 7 have been tried and give good results. Of the imported corns, Minnesota No. 13 and Wisconsin No. 7 have been among the best. Minnesota No. 23 has not been tested a very long period of time, but gives promises.

For dry-land forage purposes, it is unwise to plant the large-eared, late-maturing types of corn. They are more subject to injury, will not produce as heavy yields and will not mature seed with any certainty.

Cultivation.—The major portion of corn cultivation should be done in the preparation of the seed bed. Cultivation after planting should be relatively shallow and frequent enough to prevent weeds gaining a foothold, and prevent the formation of a crust. For this purpose, the use of a type of cultivator having numerous shovels to the gang should be used. Numerous small shovels work up the entire surface thoroly and do a better job than the larger shovels as ordinarily used. Cultivation should be approximately 4 inches deep. It is seldom wise to go deeper, as root pruning becomes severe and very injurious, especially in dry times.

Harvesting.—For forage purposes it should be the plan of the dry farmer to put his corn crop largely in the silo. Corn should be allowed to mature pretty well, at least to mature until the ears are well dented and glazed before the crop is harvested, as it will make better silage and a greater yield of feed if harvested at this time. It will not be harmful if some of the lower

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leaves are dry, because water can be run into the silage as the silo is being filled.

A home-made cutter saving all the corn crop in a dry year

If cut for fodder, it should be cut at about the same time as for silage and put at once into shocks. As soon as cured it should be taken in from the field and stacked in order to reduce the waste from the dry, high winds of winter to as low a minimum as possible. With the silo, it is possible to save 90 to 95 percent of all of the feed produced in the field. With the best methods of dry fodder making, not over 70 percent will be saved, and there will be a great deal more waste in feeding, as the animals will not eat it up nearly so completely. Often, where the crop is harvested by cutting and shocking, weather conditions will be such that as much as 80 percent may be lost, altogether too high a loss to be permitted where forage is as scarce as it is upon the ordinary plains farm.

Seed corn should be selected in the field at about the time the corn is ready to cut for fodder or silage. Only in a few sections will it be desirable to harvest corn for grain, and in those sections it will frequently be the best policy to get the grain by thrashing out well-cured fodder which has been cut at the proper time.

SORGHUMS

Two kinds of sorghums are commonly grown. Both have about equal resistance to dry weather and drouthy conditions. These are forage, or saccharine sorghums, and grain, or nonsaccharine sorghums. The latter are distinguished from the saccharine sorghums in that the juices are not sweet. They are ordinarily called grain sorghums because they produce heavy yields of

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Badly injured by hail, but the silo will save what's left

seed or grain which is well adapted for feeding purposes. The sorghums have one very valuable characteristic—in drouthy periods they will cease growth and unless the drouthy period is exceedingly prolonged, will recover and continue growth if moisture comes later. The sorghums have a very large place in the forage crops of our dry-land regions because of their ability to withstand drouth. They cannot be successfully grown in some localities, because of the cold climate resulting from the high altitudes. Where the sorghums will out-yield corn, they should be grown for forage purposes in preference to corn.

Forage Sorghums or Sorgos.—The forage sorghums can be grown practically all over the Colorado plains. In some localities near the foothills and in some localities on the Platte-Arkansas Divide, the altitudes are too high and the climate too cool for the best development of even the shortest-season sorghums.

There are a large number of varieties and types of sorghums. Practically only two types are adapted to any of our regions. These are the ambers and Sudan Grass. Of the ambers we have Black Amber, Red Amber, and White Amber. The White Amber was produced by selection by Mr. Freed, of Western Kansas. It is called in many sections, and in some government literature, "Freed's Sorgo".

Sudan Grass is not commonly called a sorghum, but for the purpose of this bulletin, it can be classed with the sorghums. It crosses readily with the ambers or other sorghums, showing its close relationship.

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Of the ambers, the Black is the best variety. Altho in our experimental work at Cheyenne Wells, the White did well, it was not equal to our local strains of Black Amber. The amber sorghums are best adapted to the southeastern portion of the State, altho they do well in the extreme eastern portion. They are less well adapted as the altitudes rise close to the mountains, but even here they may be grown to some extent.

Sudan Grass has been tried in the State for three years. It was imported from Khartum in 1909. Sudan is a province in Central Africa, of which Khartum is the leading city. On this account the Department of Agriculture officials called the grass "Sudan Grass". This grass has been tested for three years in Colorado and has given promise of being the best adapted hay crop of the forage sorghum types. It matures in a shorter season than amber, stands drouth well, and grows vigorously. Its yield will, of course, be largely according to the moisture supply available and it will vary from 1 to 8 or 9 tons. The latter yield is only possible under irrigated conditions. Sudan Grass is not adapted to the higher altitudes next to the foothills nor in the Platte-Arkansas Divide, but is adapted to the rest of the Colorado plains.

Sudan Grass, one of the best annual hay crops. This crop was hailed to the ground August 18; picture taken Sept. 28, 1915

Preparation of the Soil.—The soil for sorghums should be prepared the same as for corn. Owing to the fact that all of the sorghums are what might be termed hot weather crops, they require a warm soil before it is safe to plant. This planting should follow corn planting, usually from the 15th to the 20th of May is a safe time. Planting may even be delayed until early in June.

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If seeded broadcast, 20 to 30 pounds of amber will make a thick enough stand. In most of the dry-land regions, it will pay, however, to plant the sorghums in rows so as to permit of cultivation. Six to fifteen pounds per acre in rows, according to width of rows, will be amply sufficient upon most soils. Sudan Grass is smaller seeded and consequently a fewer number of pounds will do. If planted in rows, 3 to 6 pounds will make a sufficiently heavy stand. If planted broadcast, 10 to 15 pounds is abundantly sufficient.

Not Safe to Pasture.—Owing to the fact that the sorghums develop a poisonous principle which causes the liberation of hydrocyanic acid, commonly called prussic acid, it is unsafe in dry-land regions to pasture with livestock. This poisonous principle seemingly does not hold its effectiveness when the crop is cut and made into hay or made into silage. In other words, changes occur so that the poison is no longer injurious.

Harvesting.—If not planted too thinly, amber cane or Sudan Grass can be mowed and cured as hay. Either of these crops can be allowed to mature to be put into the silo if conditions warrant. When made into hay the crop should be raked, after allowing partial drying in the swath, immediately cocked and allowed to cure in the cock. Often cane and Sudan Grass may be harvested with the grain or corn binder. The bundles are much more easily handled than the loose hay.

GRAIN SORGHUMS

Varieties.—The grain sorghums for the most part require a longer season to properly mature than amber cane or Sudan Grass. The following varieties of grain sorghums have been tried in an experimental and practical way: Kafir, milo, kaoliang, shallu and feterita (Sudan Dura). Each of these crops is represented by a large number of varieties.

Of the kafirs, the Black Hulled White kafir has been the best. Black Hulled White kafir can only be matured in Colorado in the extreme southeastern part of the State and in a narrow belt extending along the eastern border practically as far north as Wray. It can be used for a forage considerably further west.

There is only one type of milo that should be grown in Colorado, and that is the Dwarf Yellow. The tall milos require too long a season. Dwarf Yellow milo, in Colorado, is the earliest maturing of the grain sorghums and can be grown farther north and west and at higher altitudes than any other grain sorghum now grown. In Kansas, Oklahoma and Texas, feterita is as early or earlier than Dwarf milo, but in Colorado the situation is reversed; Dwarf milo will mature in a shorter season than feterita.

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Brown kaoliang is very promising for many sections. It has been possible to mature kaoliang at higher altitudes and in cooler situations than other grain sorghum. It has about the same feeding quality and value as the kafirs. Milo and feterita are better adapted where the season is long enough to mature them. In very dry situations with excessively short seasons, kaoliang may have a place. In such locations corn does not thrive and other sorghums are not adapted.

Shallu has been tried and gives some promise. At the present time, however, the kaoliangs and shallu cannot be recommended for the Colorado plains as strongly as kafir and milo. It is advisable to confine the grain sorghum production largely to those two crops.

Feterita is a white-seeded crop, resembling milo very much, except that the heads are usually erect. Milo and feterita belong to the group of sorghums known as duras. Feterita was first tried in Colorado under the name of Sudan Dura. It is adapted to practically the same territory to which milo is adapted. It is more drouth resistant than milo, but is somewhat more adversely affected by the cool climate. As a consequence, milo is to be preferred for planting.

Methods of Planting.—All of the grain sorghums should preferably be planted in rows, whether it is expected they are to be used for grain or forage. The rows should be at least 3½ feet apart. The rate of planting should be such that kafir should have a space of 8 to 10 inches between plants (in very dry situations 12 to 15 inches); feterita should be planted about as milo. This rate of seeding will require 5 or 6 pounds of seed per acre, ordinarily. For planting, an ordinary corn planter provided with milo plates can be used. If milo plates are not at hand, blank plates can be made into milo plates by having a blacksmith drill holes of the proper size and spacing.

In the hotter, drier sections of the plains the grain sorghums will produce heavier yields of forage than corn. In such sections they should be grown for the silo or for fodder in preference to corn.

Harvesting.—When harvested for forage, these crops should be made into fodder, or preferably siloed. They should be allowed to stand in the field under ordinary conditions until the seed is practically ripe. If put into the silo earlier, they will not make as much feed and there is a tendency to the formation of a sour silage.

In addition to being valuable for forage, the seed of the grain sorghums is valuable for feeding to all kinds of animals. It is

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possible to feed the seed of amber sorghum, but it is usually not advisable. The seed coat of amber surghum is very hard and impervious to moisture. As a consequence amber sorghum seed is very much more diffcult for the animals to eat than the seed of grain sorghums. Besides, the grain sorghums, where adapted, will produce a heavier amount of seed.

Milo and feterita, when mature, have rather woody stalks and do not make a good fodder. They make a good silage, however. For fodder purposes, kafir is a much superior grain sorghum. If hay alone is desired, it is better to grow Sudan Grass or amber sorghum than any of the grain sorghum varieties.

Harvesting for Seed.—When it is desired to harvest the grain or seed of the grain sorghums, it is best to allow the crop to get ripe, then, if possible, to cut with a binder and shock.

For feeding purposes the fodder having the ripe seed can be run thru a thrashing machine as soon as the stalks are well cured. Where the seed is to be used for seed, the heads should be picked out and stored under cover. Any of the grain sorghums, if stored in bulk, are very liable to heat, and only a very slight heating is necessary to render the germ infertile. Where a corn binder is not possible, the crop can be harvested by cutting by hand or by the

A field of cane—sure roughness

use of a cutting sled. These methods are more economical of time and labor than to attempt to harvest the heads separately in the field. For seed purposes only it is possible to economically harvest heads from desirable plants in the field.

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MILLETS

Owing to the fact that they will develop with relatively small moisture supplies and that they will mature in a short season, millets must be considered among the important dry-land forage crops. Millets, as are the sorghums, are "hot weather" crops and will not do well at higher and cooler altitudes. For the most part their place among the dry-land forage crops is to furnish hay for horses, cattle and other similar livestock.

Varieties.—The varieties commonly met with on the plains are the German, Common, Hungarian, Siberian, and Hog millet. Hog millet is grown more frequently for the grain than for the forage. In some sections it will produce quite heavy yields of seed. It is not widely adapted to Colorado plains conditions. Where it is adapted it is worthy of a place in the rotation. Elsewhere, it should not be grown at all. Most of the sections where it does well lie in the northeastern part of the State.

In general, German millet is recommended in preference to others. It grows more rank than the Common, and consequently, where moisture supplies are fairly good, should be seeded a little thicker. If this precaution is taken, it will make as fine hay and usually a little more tonnage than Common. The other varieties are adapted, but do not possess any superiority. As a consequence, planting for hay purposes should be limited to the German and Common.

Preparation of the Soil.—The soil for millets must be prepared as thoroly, or more thoroly, than for sorghums and corn, as it is small seeded and must have a comparatively congenial seed bed if it is to produce a good crop. In order to accomplish the production of such a seed bed, plowing should be very early, in order to allow the accumulation and protection of the moisture supply.

Seeding.—Millet should not be seeded until approximately the first of June for most of the plains territory. It will not develop in a cold soil, and since it matures in a short season, planting can be delayed until the soil is thoroly warm, which is about the first of June. Preferably the seed should be put in with a press drill, using about 25 to 30 pounds of seed per acre. It can, however, be seeded by broadcasting and harrowing the seed in, or better still, rolling it in and following the roller with a harrow.

Harvesting.—Millet makes a valuable hay if it is cut at the right time. The right time is about the time the seed is in the milk. If allowed to mature farther than this the seed is liable

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to injure livestock to which it is fed. This is especially true of horses. When cut at the proper time, just as the seed is reaching the milk, it makes a palatable, nutritious hay. The hay can be cut and allowed to partly cure in the swath, raked and cocked for complete curing. As soon as thoroly cured, it should be stacked to prevent loss.

STOCK MELONS

Another source of possible late fall and early winter succulent feed is stock melons. Stock melons look very much like watermelons, but have a very much thicker rind. Experiments at Eads and Cheyenne Wells show that stock will eat these melons with relish. They make an excellent sod crop and if weeds are kept down will do well on old lands. They are best adapted to the hotter portions of the eastern and southeastern parts of the State. The land should be well prepared, and if sod land, the sod should be rolled flat immediately behind the plow. The melons should be planted in hills at least 10 feet apart each way. On sod land they need very little cultivation. On old lands they will need sufficient cultivation to keep the weed crop down.

The keeping quality of the melons is good, if kept from freezing. Thus they may be fed out in the fall as desired, if properly protected from being frozen, by straw or other covering.

THE GRAINS FOR HAY

A large use is already being made of many of the grains for both hay and pasture. Winter wheat and rye each make fairly good late fall and summer pasture. These two grains are the only ones at all well adapted for pasture purposes, but they are very well adapted for dry-land annual pastures. In the cooler regions, and in the northern and northwestern parts of the Colorado plains, rye is probably preferable. In the warmer portions, winter wheat will be preferable. Wheat, oats, beardless barleys, rye and emmer will each make a good quality of hay if harvested when the the seed is in the milk or soft dough stage. Often these crops will make profitable hay yields, the season taken into consideration, when the grain which is produced upon them would not be worth harvesting.

When grown for hay, these crops are planted and cared for as they would be for grain. For pasture purposes, winter wheat and rye should be seeded in July; for hay purposes, the latter part of September is preferable, where the crop is to be harvested the following year. Barley and emmer can be seeded in March if conditions are such that the land can be worked. Oats should not

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usually be seeded until the middle of April at least, on account of possible injury from late spring frosts. Wheat and rye should be seeded at the rate of about 30 to 35 pounds of seed per acre. Oats should be seeded at the rate of from 40 to 50 pounds; hulless barley should be seeded at the rate of 50 to 60 pounds, and hulled barley at about 60 pounds for hay purposes. Emmer should be seeded at the rate of 60 to 70 pounds. Each of these crops should be seeded with a press drill to obtain best results.

BROOM CORN

Broom corn is very well adapted to the southeastern portions of the State and as far west as two tiers of counties from the eastern border. This crop should not be grown in preference to other sorghums for a forage crop, but in some localities broom corn is grown for a cash crop. In such localities, if the fodder is harvested, it will make a very useful and valuable feed. Except to be used in this way, it cannot be recommended because it is not so valuable as other adapted sorghums as an exclusive forage crop. Where it is grown for the brush, however, it is worth while to take particular pains to save the fodder, which can be dry cured or siloed as circumstances permit.

WHEAT

One of the great cash crops for dry farming is winter wheat. There is no variety so well adapted as some one of the various strains of Turkey Red.

Preparation of the Soil.—Wheat in the rotation should follow corn or summer tillage. Where it follows summer tillage, the land should be plowed in June or July so as to give sufficient time for nature to compact the soil. Wheat does best on a seed bed that is loose at the surface and thoroly compacted below. Where wheat follows corn, especially if the corn has been planted in 7-foot rows, usually no preparation is necessary. The wheat is simply drilled in between the rows of corn or in the corn stubble where the corn has been cut away for silage or for fodder, as shown in illustration on cover page.

Seeding.—Turkey Red winter wheat should be seeded with a press drill, preferably a disk press drill, at the rate of 30 to 35 pounds of good seed per acre. Seeding should preferably be done by the middle of September, altho it may be done as late as the first of November in most seasons. Usually the early seeding has the advantage because it is in better shape to endure winter and gets an earlier start in the spring.

Treatment of the Seed.—No wheat should be planted except after treatment with formaldehyde or bluestone. This is necessary to check and prevent smut. The loss from smut is becoming

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so serious a problem that the slight cost of seed treatment is very cheap insurance.

BARLEY

One of the most certain grain crops for feed purposes on the plains is barley. No winter variety has yet been found which is able to withstand the dry, cold winters. Consequently, spring varieties will be used exclusively when barley appears in the cropping system. Experience has shown that barley does as well on a seed bed prepared by disking and harrowing in corn stubble as it does after summer fallow, and even better than where the land is plowed especially for this crop. In some localities fall listing, where the previous crop will permit such treatment, working the listing down in the spring to a seed bed, has been found as successful and cheaper than fall plowing.

Varieties.—The varieties of barley which do best on the plains are both two-row and six-row. Of the two-row, the Hannchen and Hanna have been the best. Of the six-row types California, or Coast, as it is now called in a good many places, and White Smyrna, a variety recently introduced by the United States Department of Agriculture, are the best, in a number of trials made at different points on the plains. The so-called Bald barley, or White Hulless barley, which is properly called Nepal, is a six-row hulless barley, probably the best of the hulless barleys for dry-land growing. This barley is better for barley hay or for hogging down than any of the two or six-row types mentioned above, but it does not yield so heavily. The best practice would be for neighborhoods to grow not over two varieties, one hulled variety and one hulless. Thus the seed problem and marketing problem would be almost automatically taken care of.

A large number of other varieties of barley have been grown and are being grown, but the varieties given have sufficient merit so that they should predominate to the exclusion of the other varieties. Barley is being grown for feed, and to some extent for a cash crop. As a feed, it supplies the same place that corn fills.

OATS

Oats are not a very successful crop on the dry lands, but may be sometimes grown. When so grown they will be grown almost entirely for feed. Oats will very rarely make yield enough to be used as a cash crop. Kherson are the best oats to use if oats are used at all.

FLAX

Flax is not adapted to the entire Colorado dry-farming area. It is well adapted to that portion of the great plains lying on the Arkansas-Platte Divide and northward. Owing to the fact that

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flax covers the land very thinly, it has been mostly a new land crop, because weeds bother very slightly on new land or breaking. On old land, weeds bother the flax crop to a considerable extent, unless the seed bed has been prepared by deep plowing.

The lack of a stable market has been the greatest drawback to the growing of flax as an auxiliary cash crop. Prices have been unusually good for a year or so, but frequently when the acreage is high, prices have been too low to be profitable. In addition to the northeastern part of the State, flax is adapted to growth in most of the foothills and intermountain regions. In such regions, however, the difficulty of marketing unless the seed is fed, makes it an undesirable crop.

Preparation of New Land.—Flax has always been considered a new-land crop. Experiments have conclusively shown, however, that the advantage of new lands is one of freedom from weeds. In breaking up new lands, if a heavy sod covers the soil, the sod should be broken from 2½ to 3½ inches deep. The furrow slice should be turned over as flatly as possible and rolled flat with a heavy roller or weighted disk, immediately after the breaking plow. Best results are obtained by plowing very early in the spring. Rolled sod can usually be made into a proper new-land seed bed by harrowing. Occasionally light disking with the disk set nearly straight, is necessary. Care should be taken to leave the sod smooth and tightly rolled down if good results are to be obtained. If plowing may be done a long time previous to seeding, the first plowing may be deep. Time and the disk harrow will put this deep plowing in proper shape for planting.

Preparation for Old Land.—The most important thing in preparing old land for flax is to have it free from weeds. Weeds cause more old-land crop failures than any other one thing. Deep plowing, if done early enough, will usually submerge the weed seeds so deeply that weeds will not bother that year. Clean corn stubble can be made into an almost perfect seed bed by disking and harrowing. Flax should be seeded with a press drill, using from 15 to 25 pounds of seed to the acre.

Time to Plant.—Flax matures in a short season, but it grows best in the cool of the season. Consequently, most of the flax should be seeded from April 10th to May 15th. Only good, bright, clean seed, treated with formaldehyde in the same manner that wheat is treated for smut should be used. Flax, owing to the danger from flax wilt, should never be grown more than one year at a time on the same land. At least three or four other crops in the rotation should be grown before it is again put upon the same tract.

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One method of marketing the dry-land corn crop

PASTURES AND NATIVE HAYS

Native Hays.—Many of the native grasses of the plains make very nutritious hays. But, except in low places or swales, the growth is normally insufficient for hay. The wheat grasses, blue-stem, and gramas are the most common native hay species.

Native Pastures.—There are still many places on the plains where there are large areas of native pasture. Where these native pastures are open range, little may be done to improve their carrying capacity. Where under fence and private control, it is possible to very materially improve carrying capacity by letting part of the pasture rest while the other portion is grazed.

Some improvement may often be made by seeding in sweet clover. This is especially true of the sandier localities.

In the high Divide country brome grass (*Bromus inermis*) does well. Here it may be seeded in the native pastures with a disk drill. The wet valleys in the sand-hills often produce brome quite well. Except under the conditions just mentioned, brome grass is very indifferently successful or a total failure.

Tame Pastures.—Tame pastures are among the most serious and difficult problems of dry farming.

No tame grass is ever successful. Brome and orchard grass may be grown in the few limited sections above mentioned. But they are not generally adapted. Yet they are the best tame grasses with which experiments have thus far been conducted.

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For hog and horse pasture, alfalfa in rows may be used. Probably for those animals which may safely be pastured upon it, alfalfa will furnish more feed than any other permanent crop.

Sweet clover will make some pasture practically anywhere on the plains, even under conditions too severe for alfalfa. It may be grazed with greater safety than alfalfa, but it is unsafe to graze sweet clover with either cattle or sheep when wet from dew or rain.

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Bulletin 228 April, 1917

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

DIVISORS

(For the Measurement of Irrigation Water)

By

V. M. CONE, Irrigation Engineer
U. S. Office of Public Roads and Rural Engineering

The work upon which this bulletin is based was done in the hydraulic laboratory, Fort Collins, Colorado, during the seasons of 1915-16, under a cooperative agreement between the Colorado Experiment Station and the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture

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DIVISORS

(For the Measurement of Irrigation Water)

By V. M. CONE, Irrigation Engineer.
U. S. Office of Public Roads and Rural Engineering

Many of the canal companies of the West are co-operative stock companies in which the individual water users have rights to proportional parts of the supply of water furnished by their canal, the divisions being in the ratio of the stock owned in the canal company. Even a few rivers have their waters divided into proportional parts among the canals, regardless of the flow in the stream at any time. Under this system it is often considered unnecessary to have the water actually measured, so long as each gets his proportionate part of all the water available in the ditch or stream. This led to the use of the divisor, division box, or proportional divisor, which are different names for a device placed in a channel for the purpose of dividing the flow into two or more parts, as might be desired.

Divisors are made in many forms and sizes. In all of them the division is made in accordance with the cross-sectional area of the box, the assumption being that the rate of flow is the same in all parts of a section across the box. This assumption is incorrect to a greater or less degree, depending upon conditions as indicated in the tables contained in this bulletin, but they are convenient devices because when they have once been set, they will give approximately the same division of the flow regardless of the later increase or decrease in the main supply. However, they are inaccurate and unreliable unless constructed and operated under definite conditions and, therefore, they should not be used as measuring devices where any considerable reliability is required.

Divisors are used extensively in some districts in Colorado and Utah, but are not known in others. As early as 1867 a divisor patterned somewhat after an Italian device was used near Greeley, Colorado, by Hon. J. Max Clark.* The Max Clark box, as it is known, is used to both measure and make a fair division of the water. Its characteristic feature is an enlargement on the upstream side of the box, which reduces the velocity of the water

*Colorado Station Bulletin 27, p. 8, and U. S. G. S. Water Supply Paper 9, p. 70.

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and thereby improves the value of the measurement.

Divisors are not generally applicable to use on rivers or large canals because of the difficulty in operating them. They are principally used on the smaller laterals.

The greater number of them are built to divide the flow in the ditch into two ditches, but they are made sometimes as a single structure to divide the stream into four parts or more. The divisor consists essentially of a flume or box placed in the ditch with one or more openings for side ditches and a partition board, or divisor board, which may be either fixed or movable. Movable partition boards are either hinged, as shown in Figures 1 to 6, or are made to move parallel to the side of the flume as shown in Figures 7 and 8. Provision is usually made for fastening the divisor board to a timber across the top of the box when the desired set has been made. Fixed divisor boards are used where the division of the flow is not often changed, but when a change in the division of the water between the two channels is desired, it is usually accomplished with this type of divisor by placing boards in a vertical position in one or the other of the channels. This method gives only approximate accuracy because it reduces the total available width of opening in the two channels and also changes the freedom of discharge.

When the proportional division of the flow gives a quantity too small for economical use, such as during a shortage of water late in the season, or when for any reason the supply is not sufficient to meet the demands of all the irrigators, it is better to give each user in turn a greater flow than his share, but for a proportionately shorter time. This amounts to dividing the total water available in a period of time rather than a division of the flow at a certain time.

To cover the full range of variations in sizes and methods of building boxes, and conditions of flow in the different channels would take an endless number of experiments. The tests on divisors were, therefore, confined to the forms shown in Figures 1 to 8, inclusive, and the accompanying tables are based upon the results of these 341 tests. In the table headings the word "divisor" means the channel or ditch which is taken out from the side of the main ditch; "width of divisor opening" is the distance from the upstream end of the partition board to the "divisor" side of the flume; "channel" is part of the box which carries the remainder of the flow of the main ditch; "head" is difference between the elevation of the water surface in the main ditch, taken 3 feet upstream from the end of the divisor board, and the top of the dam, or the floor of the box if no dam was used; and "effective head"

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is the difference between the "head" in the main ditch and the depth of water in the "divisor" taken 3 feet downstream from the point of the divisor board.

In the experimental work the divisor board was given a bevel of 1 to 4 on the "divisor" side, leaving the end about ⅛ inch thick. Rubber packing was placed under the divisor board and the board screwed to the floor of the box to insure against leakage. The flow through the "divisor" and "channel" was measured volumetrically in every experiment.

As used in the field, sometimes a drop is placed in the ditch immediately below the box, depending on which, if either, of the ditches has an excessive grade. The ditch with the drop will have the "fastest" flow, as it is commonly expressed, and, therefore, get the lion's share of the water. Since the conditions in the two ditches may be such as to produce a combination of velocities varying from slow to fast, it is evident that the divisor box cannot be classed as an accurate measuring device, and this is proved in the accompanying tables. Different types of boxes, settings of divisor board, depths of water and conditions of flow in the two ditches, are given in the tables with the hope that irrigators may know some of the facts connected with their own divisor boxes and apply the information.

A comparison of columns 2 and 3 in the tables will give the error caused by assuming the discharge to be proportional to the distances from the point of the divisor board to the sides of the flume; column 4 gives the per cent of the flow in the main ditch which will flow through the "divisor" for the corresponding width of "divisor opening" shown in column 5; and columns 6, 7 and 8 give the discharge of the "divisor", "channel", and the main ditch, respectively. To convert the discharge in second-feet, as given in columns 6, 7 and 8 into "inches" of water, multiply those values by the number of "inches" equivalent to a second-foot under the conditions in question. The quantity of water which an "inch" represents is sometimes different under neighboring canal systems.*

A dam placed across the divisor box at the point of the partition board increases the accuracy of the division of the water, its effect being most decided for low heads. When the velocity of flow was practically the same in both ditches, an effect on the division of a maximum of only approximately 1 or 2 per cent was caused by substituting a 6-inch dam for a 4-inch dam. A long box is more accurate than a short box, because the long box tends to equalize the velocities across the width of the flume be-

*See Colorado Experiment Station Bulletin No. 207.

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fore the water reaches the end of the partition board. The parallel divisor board is preferable to the swing divisor board.

In addition to the tests on divisor boxes, 196 tests were made on dividing the flow over rectangular and Cipolletti weirs. Crest lengths of 2 and 4 feet were used for both types of weirs. A thin metal plate was placed on the downstream side of the weir so that its edge touched the crest of the weir and extended vertically above the weir crest into the weir notch. This plate was set for different experiments at intervals of 2 inches across the entire width of the weir, and separate channels caught the flow over the weir on the two sides of the plate. These channels were placed far enough below the crest of the weir to allow a free passage of air under the over-pouring sheet of water. Under these conditions both types of weirs give reasonably accurate divisions, the greatest error being with the rectangular weir set to divide the flow between two parties on a basis of ¼ and ¾, when the actual deliveries will be 24 and 76 per cent for a head of 0.2 foot, and 22½ and 77½ per cent for a head of 0.8 foot. The errors with Cipolletti weirs used as divisors were in the opposite direction and about one-half as great. When either weir would be used to divide the water equally between three parties the error would be quite negligible.

If the divisor plate is placed out some distance from the weir, or the edge is placed in a horizontal position below the weir crest, the discharge for the end division would be considerably short and the flow for the middle division would be accordingly greater than the desired amount.

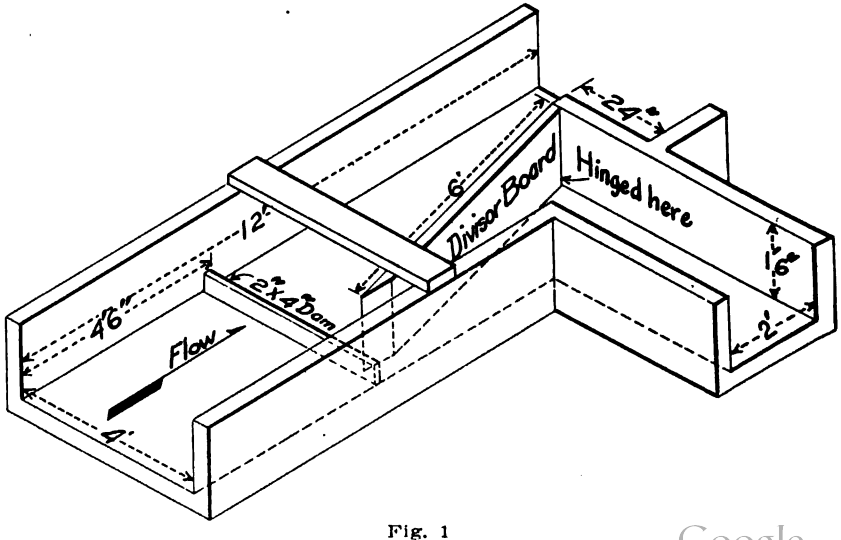

Fig. 1

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TABLE I
For Divisor Box Shown in Figure 1
Long box; 4-inch dam; divisor board hinged
24 inches from side of flume; free flow in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.2 ft. or 2⅜ inches							
1	2.1	2.8	2	1	...	...	...
2	4.2	4.9	4	2	0.1	1.2	1.3
3	6.3	6.9	6	3	0.1	1.2	1.3
4	8.3	8.9	8	4	0.1	1.1	1.2
5	10.4	10.9	10	5	0.1	1.1	1.2
6	12.5	12.9	12	6	0.2	1.1	1.3
7	14.6	14.9	15	7	0.2	1.1	1.3
8	16.7	16.9	17	8	0.2	1.0	1.2
9	18.8	19.0	19	9	0.2	1.0	1.2
10	20.8	21.0	21	10	0.3	1.0	1.3
11	22.9	23.0	23	11	0.3	1.0	1.3
12	25.0	25.1	25	12	0.3	0.9	1.2
13	27.1	27.1	27	13	0.3	0.9	1.2
14	29.2	29.1	29	14	0.4	0.9	1.3
15	31.2	31.1	31	15	0.4	0.9	1.3
16	33.4	33.2	33	16	0.4	0.8	1.2
17	35.4	35.2	35	17	0.4	0.8	1.2
18	37.5	37.2	38	18	0.5	0.8	1.3
19	39.6	39.2	40	19	0.5	0.8	1.3
20	41.7	41.2	42	20	0.5	0.7	1.2
21	43.8	43.3	44	21	0.5	0.7	1.2
22	45 8	45.3	46	22	0.6	0.7	1.3
23	47.9	47.3	48	23	0.6	0.7	1.3
24	50.0	49.3	50	24	0.6	0.6	1.2
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	2.9	2	..	...	...	...
2	4.2	5.5	4	1⅝	0.1	3.1	3.2
3	6.3	8.0	6	2¼	0.2	3.1	3.3
4	8.3	10.3	8	3	0.2	3.1	3.3
5	10.4	12.3	10	3⅞	0.3	3.1	3.4
6	12.5	14.4	12	4¾	0.4	3.1	3.5
7	14.6	16.5	15	6¼	0.5	3.0	3.5
8	16.7	18.5	17	7¼	0.6	3.0	3.6
9	18.8	20.5	19	8¼	0.7	3.0	3.7
10	20.8	22.4	21	9¼	0.7	3.0	3.7
11	22.9	24.3	23	10¼	0.8	2.9	3.7
12	25.0	26.3	25	11¼	0.9	2.9	3.8
13	27.1	28.2	27	12⅜	1.0	2.9	3.9
14	29.2	30.2	29	13⅜	1.1	2.8	3.9
15	31.2	32.1	31	14⅛	1.1	2.8	3.9
16	33.4	33.9	33	15½	1.2	2.7	3.9
17	35.4	35.8	35	16½	1.3	2.6	3.9
18	37.5	37.7	38	18⅛	1.4	2.5	3.9

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TABLE I (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
19	39.6	39.7	40	19¼	1.5	2.4	3.9
20	41.7	41.5	42	20¼	1.6	2.3	3.9
21	43.8	43.4	44	21¼	1.7	2.2	3.9
22	45.8	45.3	46	22⅜	1.8	2.1	3.9
23	47.9	47.3	48	23⅜	1.9	2.0	3.9
24	50.0	49.2	50	24½	1.9	1.9	3.8
Head = 0.8 ft. or 9⅝ inches							
1	2.1	3.6	2	..	...	...	...
2	4.2	6.7	4	1⅛	0.3	7.2	7.5
3	6.3	9.4	6	1⅝	0.4	7.2	7.6
4	8.3	11.8	8	2½	0.6	7.2	7.8
5	10.4	14.1	10	3¼	0.8	7.2	8.0
6	12.5	16.2	12	4⅛	1.0	7.2	8.2
7	14.6	18.2	15	5½	1.3	7.2	8.5
8	16.7	20.2	17	6⅝	1.5	7.2	8.7
9	18.8	22.1	19	7⅝	1.7	7.2	8.9
10	20.8	23.9	21	8½	2.0	7.1	9.1
11	22.9	25.7	23	9½	2.2	7.1	9.3
12	25.0	27.5	25	10⅝	2.5	7.1	9.6
13	27.1	29.3	27	11¾	2.7	7.0	9.7
14	29.2	31.1	29	12⅞	2.9	7.0	9.9

TABLE II

For Divisor Box Shown in Figure 1
Long box; 4-inch dam; divisor board hinged
24 inches from side of flume; 0.1 foot or 1 3-16 inches
effective head in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	2.2	2	..	...	...	...
2	4.2	4.6	4	1¾	0.1	2.3	2.4
3	6.3	6.9	6	2⅝	0.2	2.3	2.5
4	8.3	9.2	8	3½	0.2	2.3	2.5
5	10.4	11.4	10	4⅜	0.3	2.2	2.5
6	12.5	13.6	12	5¼	0.3	2.2	2.5

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TABLE II (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
7	14.6	15.8	15	6⅝	0.4	2.2	2.6
8	16.7	17.9	17	7½	0.4	2.2	2.6
9	18.8	20.0	19	8½	0.5	2.1	2.6
10	20.8	22.0	21	9½	0.6	2.1	2.7
11	22.9	24.1	23	10½	0.6	2.1	2.7
12	25.0	26.0	25	11½	0.7	2.0	2.7
13	27.1	28.1	27	12½	0.7	2.0	2.7
14	29.2	30.1	29	13½	0.8	2.0	2.8
15	31.2	32.0	31	14½	0.9	1.9	2.8
16	33.4	34.0	33	15½	1.0	1.9	2.9
17	35.4	36.0	35	16½	1.1	1.9	3.0
18	37.5	38.0	38	18	1.2	1.8	3.0
19	39.6	39.9	40	19	1.2	1.8	3.0
20	41.7	41.9	42	20	1.3	1.7	3.0
21	43.8	43.9	44	21	1.3	1.7	3.0
22	45.8	45.8	46	22	1.4	1.7	3.1
23	47.9	47.7	48	23⅛	1.5	1.6	3.1
24	50.0	49.7	50	24⅛	1.6	1.6	3.2
Head = 0.8 ft. or 9⅝ inches							
1	2.1	3.3	..	..	...	...	...
2	4.2	6.7	4	1⅛	0.2	4.8	5.0
3	6.3	9.7	6	1¾	0.3	4.5	4.8
4	8.3	12.4	8	2½	0.4	4.3	4.7
5	10.4	15.0	10	3⅛	0.5	4.2	4.7
6	12.5	17.6	12	3⅞	0.6	4.1	4.7
7	14.6	20.0	15	5	0.7	3.9	4.6
8	16.7	22.3	17	5¾	0.8	3.8	4.6
9	18.8	24.6	19	6⅝	0.9	3.8	4.7
10	20.8	26.8	21	7⅝	1.0	3.8	4.8
11	22.9	28.9	23	8¼	1.1	3.8	4.9
12	25.0	31.0	25	9¼	1.3	3.8	5.1
13	27.1	33.0	27	10⅛	1.4	3.8	5.2
14	29.2	35.0	29	11⅛	1.6	3.8	5.4

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TABLE III

For Divisor Box Shown in Figure 1

Long box; 4-inch dam; divisor board hinged

24 inches from side of flume; free flow in main channel;

0.1 foot or 1 3-16 inches effective head in divisor channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	1.0	2	1 5/8	0.1	3.1	3.2
2	4.2	2.7	4	2 3/4	0.2	3.1	3.3
3	6.3	4.4	6	4	0.2	3.1	3.3
4	8.3	6.1	8	5 1/8	0.3	3.1	3.4
5	10.4	7.8	10	6 1/4	0.4	3.0	3.4
6	12.5	9.6	12	7 5/8	0.4	3.0	3.4
7	14.6	11.3	15	9 1/8	0.5	3.0	3.5
8	16.7	13.1	17	10 1/8	0.6	2.9	3.5
9	18.8	14.9	19	11 1/4	0.7	2.9	3.6
10	20.8	16.7	21	12 1/4	0.7	2.9	3.6
11	22.9	18.5	23	13 5/8	0.8	2.8	3.6
12	25.0	20.4	25	14 5/8	0.9	2.8	3.7
13	27.1	22.3	27	15 1/8	1.0	2.7	3.7
14	29.2	24.2	29	16 1/8	1.0	2.7	3.7
15	31.2	26.2	31	17 1/2	1.1	2.6	3.7
16	33.4	28.1	33	18 5/8	1.2	2.5	3.7
17	35.4	30.0	35	19 5/8	1.2	2.4	3.6
18	37.5	31.9	38	21 1/8	1.3	2.3	3.6
19	39.6	33.8	40	22 1/8	1.4	2.2	3.6
20	41.7	35.8	42	23	1.5	2.1	3.6
21	43.8	37.8	44	24	1.6	2.0	3.6
22	45.8	39.8	..	..	...	...	...
23	47.9	41.8	..	..	...	...	...
24	50.0	43.9	..	..	...	...	...
Head = 0.8 ft. or 9 5/8 inches							
1	2.1	1.4	2	1 1/4	0.1	7.2	7.3
2	4.2	3.2	4	2 1/2	0.3	7.2	7.5
3	6.3	5.0	6	3 5/8	0.4	7.2	7.6
4	8.3	6.8	8	4 3/4	0.6	7.2	7.8
5	10.4	8.5	10	5 7/8	0.8	7.2	8.0
6	12.5	10.2	12	7	1.0	7.2	8.2
7	14.6	12.0	15	8 5/8	1.2	7.1	8.3
8	16.7	13.8	17	9 3/4	1.5	7.1	8.6
9	18.8	15.6	19	10 7/8	1.7	7.1	8.8
10	20.8	17.4	21	11 7/8	1.9	7.0	8.9

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TABLE III (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.8 ft. or 9⅝ inches							
11	22.9	19.3	23	13	2.1	7.0	9.1
12	25.0	21.2	25	14⅛	2.4	6.9	9.3
13	27.1	23.0	27	15⅛	2.6	6.9	9.5
14	29.2	24.9	29	16⅛	2.8	6.8	9.6

TABLE IV

For Divisor Box Shown in Figure 1
Long box; 4-inch dam; divisor board hinged
24 inches from side of flume; free flow in divisor channel
and 0.1 foot or 1 3-16 inches effective head in main channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	5.0	2	..	...	...	...
2	4.2	8.1	4	0¾	0.1	2.3	2.4
3	6.3	11.0	6	1⅜	0.1	2.3	2.4
4	8.3	13.8	8	2	0.2	2.3	2.5
5	10.4	16.6	10	2⅝	0.2	2.3	2.5
6	12.5	19.3	12	3⅜	0.3	2.3	2.6
7	14.6	21.8	15	4⅜	0.4	2.2	2.6
8	16.7	24.3	17	5⅛	0.5	2.2	2.7
9	18.8	26.5	19	5⅞	0.5	2.2	2.7
10	20.8	28.7	21	6¾	0.6	2.2	2.8
11	22.9	30.9	23	7½	0.6	2.2	2.8
12	25.0	33.0	25	8⅜	0.7	2.1	2.8
13	27.1	34.9	27	9¼	0.8	2.1	2.9
14	29.2	36.8	29	10⅛	0.9	2.1	3.0
15	31.2	38.7	31	11	0.9	2.1	3.0
16	33.4	40.6	33	12	1.0	2.0	3.0
17	35.4	42.4	35	13	1.1	2.0	3.1
18	37.5	44.2	38	14⅝	1.2	1.9	3.1

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TABLE IV (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
19	39.6	46.0	40	15¾	1.3	1.9	3.2
20	41.7	47.8	42	16¾	1.4	1.9	3.3
21	43.8	49.6	44	17⅞	1.5	1.8	3.3
22	45.8	51.3	46	19	1.6	1.8	3.4
23	47.9	53.0	48	20⅛	1.7	1.7	3.4
24	50.0	54.7	50	21¼	1.7	1.7	3.4
Head = 0.8 ft. or 9⅝ inches							
1	2.1	5.2	..	..	...	...	...
2	4.2	10.0	4	0¾	0.2	4.9	5.1
3	6.3	14.3	6	1⅛	0.3	4.7	5.0
4	8.3	18.3	8	1⅝	0.4	4.6	5.0
5	10.4	22.0	10	2	0.5	4.5	5.0
6	12.5	25.4	12	2⅛	0.6	4.3	4.9
7	14.6	28.3	15	3⅛	0.7	4.2	4.9
8	16.7	31.0	17	3⅝	0.8	4.1	4.9
9	18.8	33.5	19	4⅛	0.9	4.0	4.9
10	20.8	35.7	21	4¾	1.0	3.9	4.9
11	22.9	37.8	23	5¼	1.1	3.9	5.0
12	25.0	39.7	25	5⅞	1.3	3.8	5.1
13	27.1	41.5	27	6½	1.4	3.8	5.2
14	29.2	43.2	29	7¼	1.5	3.8	5.3

TABLE V

For Divisor Box Shown in Figure 2
Long box; no dam; divisor board hinged 24 inches from side of flume; free flow in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.2 ft. or 2⅜ icnhes							
1	2.1	8.9	2	..	...	...	...
2	4.2	11.7	4	..	...	...	...
3	6.3	14.4	6	..	...	...	...
4	8.3	17.2	8	..	...	...	...
5	10.4	19.7	10	1⅜	0.1	0.6	0.7
6	12.5	22.2	12	2⅛	0.1	0.6	0.7

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TABLE V (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.2 ft. or 2⅜ inches							
7	14.6	24.6	15	3¼	0.1	0.6	0.7
8	16.7	26.7	17	4	0.1	0.6	0.7
9	18.8	28.7	19	4¾	0.1	0.6	0.7
10	20.8	30.6	21	5⅛	0.2	0.6	0.8
11	22.9	32.4	23	6⅝	0.2	0.6	0.8
12	25.0	34.1	25	7¼	0.2	0.6	0.8
13	27.1	35.6	27	8⅛	0.2	0.6	0.8
14	29.2	37.1	29	9⅛	0.3	0.6	0.9
15	31.2	38.4	31	10¼	0.3	0.6	0.9
16	33.4	39.7	33	11⅝	0.3	0.6	0.9
17	35.4	40.8	35	12⅝	0.3	0.6	0.9
18	37.5	41.9	38	14⅝	0.4	0.7	1.1
19	39.6	42.8	40	16¼	0.4	0.7	1.1
20	41.7	43.6	42	18⅛	0.5	0.7	1.2
21	43.8	44.3	44	20⅝	0.5	0.7	1.2
22	45.8	44.9	46	24	0.6	0.7	1.3
23	47.9	45.4	..	..	...	...	...
24	50.0	45.9	..	..	...	...	...
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	6.8	2	..	...	...	...
2	4.2	9.6	4	..	...	...	...
3	6.3	12.4	6	0¾	0.1	1.6	1.7
4	8.3	15.1	8	1½	0.1	1.6	1.7
5	10.4	17.9	10	2⅛	0.2	1.7	1.9
6	12.5	20.6	12	2¾	0.2	1.7	1.9
7	14.6	22.9	15	3⅞	0.3	1.7	2.0
8	16.7	25.2	17	4⅝	0.4	1.7	2.1
9	18.8	27.4	19	5⅝	0.4	1.7	2.1
10	20.8	29.5	21	6¼	0.5	1.7	2.2
11	22.9	31.4	23	7	0.5	1.8	2.3
12	25.0	33.3	25	7⅞	0.6	1.8	2.4
13	27.1	35.0	27	8¾	0.6	1.8	2.4
14	29.2	36.6	29	9¾	0.7	1.8	2.5
15	31.2	38.0	31	10¾	0.8	1.8	2.6
16	33.4	39.3	33	11⅞	0.9	1.9	2.8
17	35.4	40.5	35	13	1.0	1.9	2.9
18	37.5	41.6	38	15	1.1	1.9	3.0
19	39.6	42.5	40	16½	1.2	2.0	3.2
20	41.7	43.3	42	18½	1.4	2.0	3.4
21	43.8	44.1	44	21	1.6	2.0	3.6
22	45.8	44.7	45	22½	1.7	2.1	3.8
23	47.9	45.3	..	..	...	...	...
24	50.0	45.8	..	..	...	...	...

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TABLE V (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.6 ft. or 7 3-16 inches							
1	2.1	6.3	2	..	...	...	...
2	4.2	9.2	4	..	...	...	...
3	6.3	12.1	6	0⅞	0.2	3.0	3.2
4	8.3	14.8	8	1⅝	0.2	3.0	3.2
5	10.4	17.5	10	2¼	0.3	3.0	3.3
6	12.5	20.2	12	3	0.4	3.0	3.4
7	14.6	22.6	15	4	0.5	3.1	3.6
8	16.7	24.9	17	4¾	0.7	3.1	3.8
9	18.8	27.1	19	5½	0.8	3.1	3.9
10	20.8	29.2	21	6⅜	0.9	3.1	4.0
11	22.9	31.1	23	7¼	1.0	3.2	4.2
12	25.0	32.9	25	8	1.1	3.2	4.3
13	27.1	34.7	27	9	1.3	3.2	4.5
14	29.2	36.3	29	10	1.4	3.2	4.6
15	31.2	37.7	31	11	1.5	3.3	4.8
16	33.4	39.1	33	12	1.7	3.3	5.0
17	35.4	40.2	35	13¼	1.9	3.3	5.2
18	37.5	41.3	38	15¼	2.1	3.4	5.5
19	39.6	42.2	40	16¾	2.3	3.4	5.7
20	41.7	43.1	42	18¾	2.6	3.5	6.1
21	43.8	43.8	44	21¼	2.9	3.5	6.4
22	45.8	44.5	45	22⅞	3.1	3.6	6.7
23	47.9	45.1	..	..	...	...	...
24	50.0	45.7	..	..	...	...	...
Head = 0.8 ft. or 9⅝ inches							
1	2.1	6.3	2	..	...	...	...
2	4.2	8.8	4	..	...	...	...
3	6.3	11.7	6	1	0.3	4.6	4.9
4	8.3	14.6	8	1⅝	0.4	4.6	5.0
5	10.4	17.2	10	2⅝	0.5	4.7	5.2
6	12.5	19.8	12	3⅛	0.7	4.7	5.4
7	14.6	22.2	15	4⅛	0.9	4.8	5.7
8	16.7	24.6	17	5	1.1	4.8	5.9
9	18.8	26.8	19	5¾	1.2	4.8	6.0
10	20.8	28.8	21	6½	1.3	4.9	6.2
11	22.9	30.8	23	7¼	1.5	4.9	6.4
12	25.0	32.7	25	8⅛	1.7	5.0	6.7
13	27.1	34.4	27	9⅛	1.9	5.0	6.9
14	29.2	36.1	29	10⅛	2.1	5.1	7.2
15	31.2	37.6	31	11⅛	2.3	5.1	7.4
16	33.4	38.8	33	12⅛	2.5	5.2	7.7

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TABLE V (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 1.0 ft. or 12 inches							
1	2.1	5.7	2	..	...	...	...
2	4.2	8.7	4	..	...	...	...
3	6.3	11.5	6	1⅛	0.4	6.4	6.8
4	8.3	14.2	8	1¾	0.6	6.5	7.1
5	10.4	16.9	10	2⅛	0.7	6.5	7.2
6	12.5	19.5	12	3¼	0.9	6.6	7.5
7	14.6	22.0	15	4⅛	1.2	6.7	7.9
8	16.7	24.4	17	5	1.4	6.8	8.2
9	18.8	26.6	19	5⅝	1.7	6.8	8.5
10	20.8	28.7	21	6⅝	1.9	6.9	8.8
11	22.9	30.7	23	7⅝	2.1	7.0	9.1
12	25.0	32.5	25	8¼	2.4	7.1	9.5

TABLE VI

For Divison Box Shown in Figure 2
Long box; no dam; divisor board hinged 24 inches from side of flume; 0.1 ft. or 1 3-16 inch effective head in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	4.0	2	..	...	...	...
2	4.2	7.8	4	1	0.1	1.5	1.6
3	6.3	10.6	6	1⅝	0.1	1.5	1.6
4	8.3	13.8	8	2¼	0.2	1.6	1.8
5	10.4	16.7	10	2¾	0.2	1.6	1.8
6	12.5	19.5	12	3⅜	0.2	1.6	1.8
7	14.6	22.1	15	4⅜	0.3	1.6	1.9
8	16.7	24.5	17	5⅛	0.4	1.6	2.0
9	18.8	26.8	19	5¾	0.4	1.6	2.0
10	20.8	28.9	21	6⅝	0.5	1.7	2.2
11	22.9	31.0	23	7⅝	0.5	1.7	2.2
12	25.0	33.0	25	8¼	0.6	1.7	2.3
13	27.1	34.8	27	9⅛	0.7	1.7	2.4
14	29.2	36.6	29	10	0.7	1.7	2.4
Head = 0.8 ft. or 9⅝ inches							
1	2.1	4.0	2	..	...	...	...
2	4.2	7.7	4	1	0.1	3.2	3.3
3	6.3	11.2	6	1½	0.2	3.3	3.5
4	8.3	14.6	8	2⅛	0.3	3.3	3.6
5	10.4	18.0	10	2⅝	0.4	3.4	3.8

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TABLE VI (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.8 ft. or 9⅝ inches							
6	12.5	21.2	12	3¼	0.5	3.4	3.9
7	14.6	24.3	15	4⅛	0.7	3.5	4.2
8	16.7	27.1	17	4⅝	0.9	3.5	4.4
9	18.8	29.8	19	5¼	1.0	3.6	4.6
10	20.8	32.4	21	5⅞	1.1	3.6	4.7
11	22.9	34.8	23	6⅝	1.2	3.7	4.9
12	25.0	37.1	25	7¼	1.4	3.7	5.1
13	27.1	39.3	27	8	1.5	3.8	5.3
14	29.2	41.3	29	8⅝	1.6	3.8	5.4

TABLE VII

For Divisor Shown in Figure 2

Long box; no dam; divisor board hinged 24 inches from side of flume: 0.1 ft. or 1 3-16 inches, effective head in divisor channel, and free flow in main channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	4.7	2	..	...	...	...
2	4.2	7.5	4	0¾	0.1	1.6	1.7
3	6.3	10.2	6	1⅛	0.1	1.6	1.7
4	8.3	12.9	8	2¼	0.2	1.7	1.9
5	10.4	15.6	10	2⅞	0.2	1.7	1.9
6	12.5	18.3	12	3⅝	0.3	1.7	2.0
7	14.6	20.8	15	4¾	0.3	1.7	2.0
8	16.7	23.3	17	5½	0.4	1.7	2.1
9	18.8	25.7	19	6¼	0.4	1.7	2.1
10	20.8	27.9	21	7⅛	0.5	1.8	2.3
11	22.9	30.1	23	7⅞	0.6	1.8	2.4
12	25.0	32.2	25	8¾	0.6	1.8	2.4
13	27.1	34.2	27	9⅝	0.7	1.8	2.5
14	29.2	36.1	29	10⅛	0.8	1.8	2.6
Head = 0.8 ft. or 9⅝ inches							
1	2.1	4.0	2	..	...	...	...
2	4.2	6.9	4	1	0.2	4.6	4.8
3	6.3	9.8	6	1¾	0.3	4.6	4.9
4	8.3	12.6	8	2⅝	0.5	4.7	5.2
5	10.4	15.4	10	3	0.6	4.7	5.3

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TABLE VII (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.8 ft. or 9⅝ inches							
6	12.5	18.0	12	3¾	0.7	4.7	5.4
7	14.6	20.5	15	4⅛	0.9	4.8	5.7
8	16.7	23.0	17	5⅝	1.0	4.8	5.8
9	18.8	25.4	19	6⅜	1.2	4.9	6.1
10	20.8	27.8	21	7¼	1.4	4.9	6.3
11	22.9	30.2	23	8	1.5	4.9	6.4
12	25.0	32.4	25	8¾	1.7	5.0	6.7
13	27.1	34.7	27	9⅝	1.9	5.0	6.9
14	29.2	36.9	29	10½	2.0	5.1	7.1

TABLE VIII

For Divisor Shown in Figure 2
Long box; no dam; divisor board hinged 24 inches from side of flume; 0.1 ft. or 1 3-16 inches effective head in main channel, and free flow in divisor channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	4.0	2	..	...	...	...
2	4.2	7.3	4	1	0.1	1.5	1.6
3	6.3	10.6	6	1⅝	0.1	1.5	1.6
4	8.3	13.7	8	2¼	0.2	1.6	1.8
5	10.4	16.6	10	2¾	0.2	1.6	1.8
6	12.5	19.3	12	3½	0.3	1.6	1.9
7	14.6	21.9	15	4⅜	0.3	1.6	1.9
8	16.7	24.3	17	5⅛	0.4	1.6	2.0
9	18.8	26.4	19	5⅞	0.4	1.6	2.0
10	20.8	28.5	21	6⅝	0.5	1.6	2.1
11	22.9	30.4	23	7½	0.5	1.7	2.2
12	25.0	32.2	25	8⅜	0.6	1.7	2.3
13	27.1	33.8	27	9¼	0.7	1.7	2.4
14	29.2	35.3	29	10¼	0.8	1.7	2.5
15	31.2	36.7	31	11⅜	0.8	1.8	2.6
16	33.4	38.0	33	12½	0.9	1.8	2.7
17	35.4	39.3	35	13¾	1.0	1.8	2.8
18	37.5	40.5	38	16	1.2	1.9	3.1

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TABLE VIII (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
19	39.6	41.6	40	17 5/8	1.3	1.9	3.2
20	41.7	42.6	42	19 3/8	1.4	1.9	3.3
21	43.8	43.6	44	21 3/8	1.6	2.0	3.6
22	45.8	44.6	46	23 1/2	1.7	2.0	3.7
23	47.9	45.6	..	..	...	...	...
24	50.0	46.5	..	..	...	...	...
Head = 0.8 ft. or 9 5/8 inches							
1	2.1	5.0	2	..	...	...	...
2	4.2	10.0	4	0 3/4	0.1	3.2	3.3
3	6.3	14.3	6	1 1/4	0.3	3.2	3.5
4	8.3	18.2	8	1 7/8	0.3	3.3	3.6
5	10.4	21.7	10	2	0.4	3.3	3.7
6	12.5	24.7	12	2 1/2	0.5	3.3	3.8
7	14.6	27.4	15	3 1/4	0.6	3.4	4.0
8	16.7	29.8	17	3 7/8	0.7	3.4	4.1
9	18.8	32.0	19	4 1/4	0.8	3.5	4.3
10	20.8	34.0	21	4 3/4	1.0	3.5	4.5
11	22.9	35.8	23	5 3/8	1.1	3.6	4.7
12	25.0	37.5	25	6 1/8	1.2	3.6	4.8
13	27.1	38.9	27	6 7/8	1.4	3.7	5.1
14	29.2	40.3	29	7 5/8	1.6	3.8	5.4

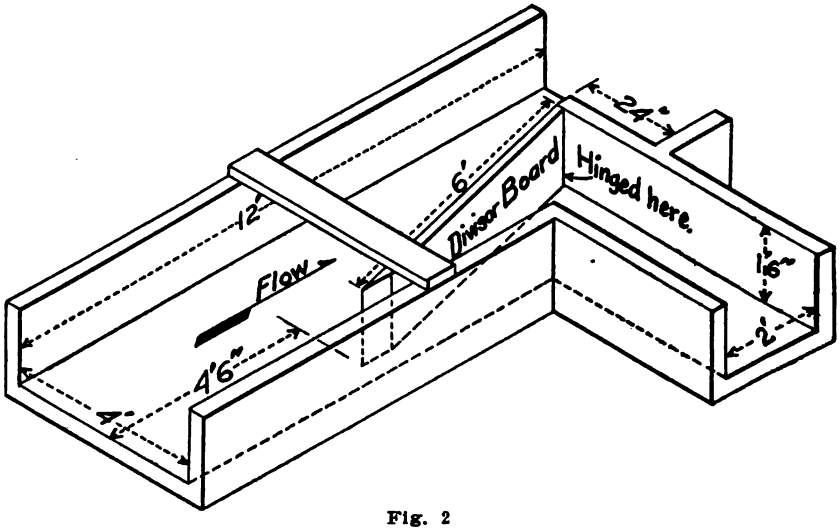

Fig. 2

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TABLE IX

For Divisor Box Shown in Figure 3

Short box; 4-inch dam; divisor board hinged 24 inches from side of flume; free flow in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.2 ft. or 2⅜ inches							
1	2.1	2.0	..	..	...	...	...
2	4.2	4.0	4	2	...	...	...
3	6.3	6.0	6	3	0.1	1.1	1.2
4	8.3	8.0	8	4	0.1	1.1	1.2
5	10.4	10.0	10	5	0.1	1.1	1.2
6	12.5	12.0	12	6	0.2	1.0	1.2
7	14.6	14.0	15	7½	0.2	1.0	1.2
8	16.7	16.1	17	8⅝	0.2	1.0	1.2
9	18.8	18.2	19	9⅝	0.2	1.0	1.2
10	20.8	20.2	21	10⅝	0.3	0.9	1.2
11	22.9	22.3	23	11⅝	0.3	0.9	1.2
12	25.0	24.3	25	12¼	0.3	0.9	1.2
13	27.1	26.4	27	13¼	0.3	0.9	1.2
14	29.2	28.5	29	14¼	0.4	0.8	1.2
15	31.2	30.6	31	15¼	0.4	0.8	1.2
16	33.4	32.7	33	16⅛	0.4	0.8	1.2
17	35.4	34.7	35	17⅛	0.4	0.8	1.2
18	37.5	36.8	38	18½	0.5	0.7	1.2
19	39.6	39.0	40	19½	0.5	0.7	1.2
20	41.7	41.1	42	20⅝	0.5	0.7	1.2
21	43.8	43.2	44	21⅝	0.5	0.7	1.2
22	45.8	45.3	46	22¼	0.5	0.7	1.2
23	47.9	47.4	48	23¼	0.6	0.6	1.2
24	50.0	49.6	50	24¼	0.6	0.6	1.2
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	1.8	2	1⅛	0.1	2.9	3.0
2	4.2	3.6	4	2⅛	0.1	2.9	3.0
3	6.3	5.5	6	3⅛	0.2	2.9	3.1
4	8.3	7.4	8	4⅜	0.3	2.8	3.1
5	10.4	9.3	10	5⅜	0.3	2.8	3.1
6	12.5	11.2	12	6⅜	0.4	2.8	3.2
7	14.6	13.2	15	7⅞	0.5	2.7	3.2
8	16.7	15.2	17	8⅞	0.5	2.7	3.2
9	18.8	17.2	19	9⅞	0.6	2.6	3.2
10	20.8	19.2	21	10⅞	0.7	2.6	3.3
11	22.9	21.3	23	11¾	0.7	2.6	3.3
12	25.0	23.4	25	12¾	0.8	2.5	3.3
13	27.1	25.6	27	13⅝	0.9	2.4	3.3
14	29.2	27.7	29	14⅝	0.9	2.4	3.3
15	31.2	29.9	31	15½	1.0	2.3	3.3
16	33.4	32.1	33	16⅝	1.1	2.2	3.3
17	35.4	34.3	35	17⅞	1.1	2.2	3.3
18	37.5	36.5	38	18⅝	1.2	2.1	3.3

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TABLE IX (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
19	39.6	38.7	40	19⅝	1.3	2.0	3.3
20	41.7	40.9	42	20½	1.4	1.9	3.3
21	43.8	43.2	44	21⅝	1.4	1.9	3.3
22	45.8	45.3	46	22¼	1.5	1.8	3.3
23	47.9	47.5	48	23¼	1.6	1.7	3.3
24	50.0	49.7	50	24⅛	1.7	1.7	3.4
Head = 0.8 ft. or 9⅝ inches							
1	2.1	2.5	2	0¾	0.1	6.6	6.7
2	4.2	4.6	4	1¾	0.3	6.6	6.9
3	6.3	6.7	6	2⅝	0.4	6.6	7.0
4	8.3	8.8	8	3⅝	0.6	6.5	7.1
5	10.4	10.9	10	4½	0.7	6.5	7.2
6	12.5	13.1	12	5½	0.9	6.5	7.4
7	14.6	15.2	15	7	1.2	6.4	7.6
8	16.7	17.3	17	7⅞	1.3	6.4	7.7
9	18.8	19.4	19	8⅞	1.5	6.3	7.8
10	20.8	21.5	21	9¾	1.7	6.3	8.0
11	22.9	23.6	23	10¾	1.9	6.2	8.1
12	25.0	25.7	25	11⅝	2.0	6.2	8.2
13	27.1	27.7	27	12⅝	2.2	6.1	8.3
14	29.2	29.8	29	13⅝	2.4	6.0	8.4

TABLE X

For Divisor Box Shown in Figure 3

Short box; 4-inch dam; divisor board hinged 24 inches from side of flume, 0.1 ft. or 1 3-16 inches effective in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	1.3	2	1⅛	0.1	2.1	2.2
2	4.2	2.7	4	2⅝	0.1	2.1	2.2
3	6.3	4.5	6	3¾	0.1	2.1	2.2
4	8.3	6.4	8	4¾	0.2	2.1	2.3
5	10.4	8.4	10	5¾	0.2	2.1	2.3
6	12.5	10.4	12	6¾	0.3	2.1	2.4

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TABLE X (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
7	14.6	12.5	15	8¼	0.4	2.0	2.4
8	16.7	14.6	17	9⅛	0.4	2.0	2.4
9	18.8	16.7	19	10⅛	0.4	2.0	2.4
10	20.8	18.8	21	11	0.5	1.9	2.4
11	22.9	20.9	23	12	0.5	1.9	2.4
12	25.0	23.0	25	13	0.6	1.8	2.4
13	27.1	25.1	27	13⅞	0.6	1.8	2.4
14	29.2	27.2	29	14⅞	0.7	1.8	2.5
15	31.2	29.3	31	15⅞	0.8	1.7	2.5
16	33.4	31.3	33	16¾	0.8	1.7	2.5
17	35.4	33.4	35	17¾	0.9	1.6	2.5
18	37.5	35.6	38	19⅛	0.9	1.6	2.5
19	39.6	37.7	40	20	1.0	1.5	2.5
20	41.7	39.9	42	21	1.0	1.5	2.5
21	43.8	42.0	44	21⅞	1.1	1.4	2.5
22	45.8	44.2	46	22⅞	1.2	1.3	2.5
23	47.9	46.3	48	23¾	1.2	1.3	2.5
24	50.0	48.4	50	24⅞	1.3	1.2	2.5

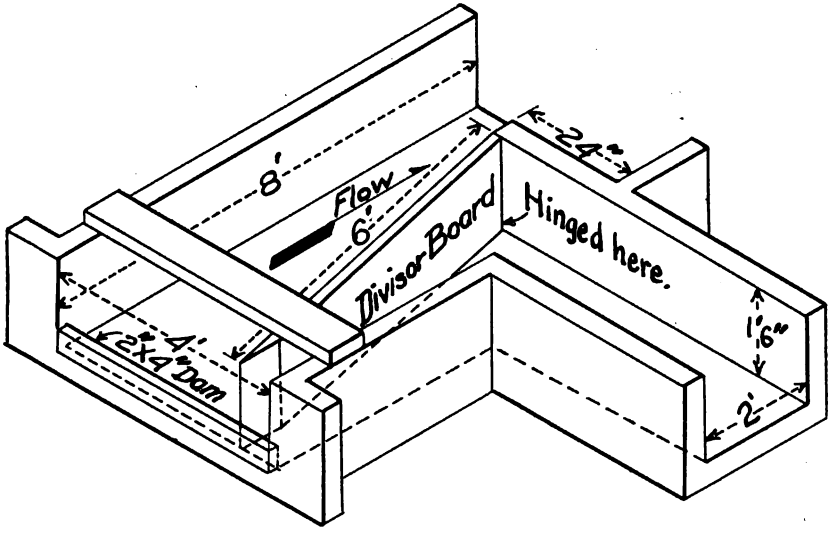

Fig. 3

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TABLE X (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
			Head = 0.8 ft. or 9⅝ inches				
1	2.1	1.7	2	1⅛	0.1	3.7	3.8
2	4.2	3.4	4	2⅜	0.2	3.8	4.0
3	6.3	5.2	6	3⅝	0.3	3.9	4.2
4	8.3	7.0	8	4½	0.4	3.9	4.3
5	10.4	9.0	10	5½	0.5	3.9	4.4
6	12.5	10.9	12	6½	0.6	3.9	4.5
7	14.6	12.9	15	8	0.7	3.9	4.6
8	16.7	14.9	17	9	0.8	3.9	4.7
9	18.8	17.0	19	10	0.9	3.8	4.7
10	20.8	19.0	21	10⅞	1.0	3.7	4.7
11	22.9	21.1	23	11⅞	1.1	3.6	4.7
12	25.0	23.2	25	12⅞	1.2	3.6	4.8
13	27.1	25.3	27	13¾	1.3	3.5	4.8
14	29.2	27.4	29	14¾	1.5	3.4	4.9

TABLE XI

For Divisor Box Shown in Figure 3
Short box; 4-inch dam; divisor board hinged 24 inches from side of flume; free flow in main channel; 0.1 ft. or 1 3-16 inches effective head in divisor channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
			Head = 0.4 ft. or 4 13-16 inches				
1	2.1	1.0	2	2	0.1	2.9	3.0
2	4.2	2.0	4	3⅞	0.1	2.9	3.0
3	6.3	3.0	6	5½	0.2	2.8	3.0
4	8.3	4.1	8	7	0.3	2.7	3.0
5	10.4	5.3	10	8¼	0.3	2.8	3.1
6	12.5	6.7	12	9½	0.4	2.7	3.1
7	14.6	8.1	15	11¼	0.5	2.6	3.1
8	16.7	9.6	17	12⅝	0.5	2.6	3.1
9	18.8	11.1	19	13½	0.6	2.5	3.1
10	20.8	12.7	21	14⅝	0.7	2.4	3.1
11	22.9	14.4	23	15⅝	0.7	2.4	3.1
12	25.0	16.2	25	16⅝	0.7	2.3	3.0
13	27.1	18.0	27	17⅝	0.8	2.2	3.0
14	29.2	19.8	29	18⅝	0.9	2.1	3.0
15	31.2	21.8	31	19⅝	0.9	2.1	3.0
16	33.4	23.8	33	20½	1.0	2.0	3.0
17	35.4	25.8	35	21½	1.0	2.0	3.0
18	37.5	27.8	38	22⅞	1.1	1.8	2.9

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TABLE XI (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
19	39.6	29.8	40	23¾	1.2	1.7	2.9
20	41.7	31.9	42	24⅝	1.2	1.7	2.9
21	43.8	34.0	..	..	...	...	...
22	45.8	36.1	..	..	...	...	...
23	47.9	37.3	..	..	...	...	...
24	50.0	40.5	..	..	...	...	...
Head = 0.8 ft. or 9⅝ inches							
1	2.1	....	2	3¾	0.1	6.5	6.6
2	4.2	1.0	4	5⅝	0.3	6.5	6.8
3	6.3	1.5	6	7⅛	0.4	6.4	6.8
4	8.3	2.4	8	8⅝	0.5	6.4	6.9
5	10.4	3.3	10	9⅞	0.7	6.3	7.0
6	12.5	4.5	12	11	0.8	6.2	7.0
7	14.6	5.7	15	12¾	1.1	6.1	7.2
8	16.7	7.2	17	13⅞	1.2	6.0	7.2
9	18.8	8.7	19	14⅞	1.4	5.9	7.3
10	20.8	10.3	..	..	...	...	...
11	22.9	11.9	..	..	...	...	...
12	25.0	13.7	..	..	...	...	...
13	27.1	15.5	..	..	...	...	...
14	29.2	17.3	..	..	...	...	...

TABLE XII

For Divisor Box Shown in Figure 3

Short box; 4-inch dam; divisor board hinged 24 inches from side of flume; free flow in divisor channel; 0.1 ft. or 1 3-16 inches effective head in main channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	3.7	2	..	...	...	...
2	4.2	6.2	4	1⅛	0.1	2.2	2.3
3	6.3	8.7	6	1⅞	0.1	2.2	2.3
4	8.3	11.2	8	2¾	0.2	2.1	2.3
5	10.4	13.7	10	3½	0.2	2.2	2.4
6	12.5	16.2	12	4¼	0.3	2.1	2.4

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TABLE XII (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
7	14.6	17.7	15	5½	0.4	2.1	2.5
8	16.7	21.2	17	6¼	0.4	2.1	2.5
9	18.8	23.7	19	7⅛	0.5	2.0	2.5
10	20.8	26.2	21	7⅞	0.6	2.0	2.6
11	22.9	28.6	23	8⅝	0.6	2.0	2.6
12	25.0	30.9	25	9½	0.6	2.0	2.6
13	27.1	33.3	27	10⅜	0.7	2.0	2.7
14	29.2	35.7	29	11¼	0.8	1.9	2.7
15	31.2	38.0	31	12	0.8	1.9	2.7
16	33.4	40.3	33	12⅞	0.9	1.8	2.7
17	35.4	42.5	35	13⅝	0.9	1.8	2.7
18	37.5	44.7	38	15	1.0	1.8	2.8
19	39.6	46.9	40	15⅞	1.1	1.7	2.8
20	41.7	49.1	42	16⅝	1.2	1.6	2.8
21	43.8	51.3	44	17¾	1.2	1.6	2.8
22	45.8	53.5	46	18⅝	1.3	1.5	2.8
23	47.9	55.6	48	19½	1.4	1.5	2.9
24	50.0	57.7	50	20½	1.4	1.5	2.9
Head = 0.8 ft. or 9⅝ inches							
1	2.1	6.6	2	..	...	...	...
2	4.2	9.9	4	..	...	...	...
3	6.3	13.2	6	0⅞	0.2	3.7	3.9
4	8.3	16.4	8	1⅝	0.3	3.8	4.1
5	10.4	19.5	10	2	0.4	3.8	4.2
6	12.5	22.4	12	2⅝	0.5	3.9	4.4
7	14.6	25.3	15	3⅝	0.7	3.9	4.6
8	16.7	28.1	17	4¼	0.8	3.9	4.7
9	18.8	30.7	19	4⅞	0.9	3.9	4.8
10	20.8	33.3	21	5½	1.0	3.9	4.9
11	22.9	35.8	23	6¼	1.2	3.9	5.1
12	25.0	38.2	25	6⅞	1.3	3.9	5.2
13	27.1	40.5	27	7⅝	1.4	3.9	5.3
14	29.2	42.8	29	8⅜	1.5	3.9	5.4

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TABLE XIII

For Divisor Box Shown in Figure 4

Short box; floor flush with top of 4-inch dam; divisor board hinged 24 inches from side of flume; free flow in both channels.

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.2 ft. or 2⅝ inches							
1	2.1	....	..	..	...	...	...
2	4.2	1.4	4	3⅞	0.1	0.9	1.0
3	6.3	2.6	6	5⅝	0.1	0.9	1.0
4	8.3	3.8	8	6⅝	0.1	0.9	1.0
5	10.4	5.4	10	7⅝	0.1	0.9	1.0
6	12.5	7.0	12	8⅝	0.1	0.9	1.0
7	14.6	8.8	15	10	0.2	0.8	1.0
8	16.7	10.7	17	10⅞	0.2	0.8	1.0
9	18.8	12.8	19	11¾	0.2	0.8	1.0
10	20.8	15.0	21	12⅝	0.2	0.8	1.0
11	22.9	17.3	23	13½	0.2	0.8	1.0
12	25.0	19.6	25	14¼	0.2	0.7	0.9
13	27.1	21.9	27	15⅛	0.3	0.7	1.0
14	29.2	24.3	29	16	0.3	0.7	1.0
15	31.2	26.7	31	16¾	0.3	0.7	1.0
16	33.4	29.1	33	17½	0.3	0.7	1.0
17	35.4	31.6	35	18⅜	0.3	0.6	0.9
18	37.5	34.2	38	19½	0.4	0.6	1.0
19	39.6	36.7	40	20¼	0.4	0.6	1.0
20	41.7	39.2	42	21⅛	0.4	0.6	1.0
21	43.8	41.6	44	22	0.4	0.6	1.0
22	45.8	44.0	46	22⅞	0.5	0.5	1.0
23	47.9	46.5	48	23⅝	0.5	0.5	1.0
24	50.0	47.8	50	24½	0.5	0.5	1.0
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	....	2	2⅛	0.1	2.7	2.8
2	4.2	1.4	4	3⅞	0.1	2.7	2.8
3	6.3	2.6	6	5⅝	0.2	2.6	2.8
4	8.3	3.9	8	6⅝	0.2	2.6	2.8
5	10.4	5.4	10	7⅝	0.3	2.5	2.8
6	12.5	7.0	12	8⅝	0.4	2.4	2.8
7	14.6	8.8	15	10	0.4	2.4	2.8
8	16.7	10.7	17	10⅞	0.5	2.3	2.8
9	18.8	12.8	19	11¾	0.5	2.3	2.8
10	20.8	15.0	21	12⅝	0.6	2.2	2.8
11	22.9	17.3	23	13½	0.6	2.2	2.8
12	25.0	19.6	25	14¼	0.7	2.1	2.8

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TABLE XIII (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
13	27.1	21.9	27	15 1/8	0.8	2.0	2.8
14	29.2	24.3	29	16	0.8	2.0	2.8
15	31.2	26.7	31	16 3/4	0.9	1.9	2.8
16	33.4	29.1	33	17 1/2	0.9	1.9	2.8
17	35.4	31.6	35	18 5/8	1.0	1.8	2.8
18	37.5	34.2	38	19 1/2	1.1	1.7	2.8
19	39.6	36.7	40	20 1/4	1.1	1.7	2.8
20	41.7	39.2	42	21 1/8	1.2	1.6	2.8
21	43.8	41.6	44	22	1.2	1.6	2.8
22	45.8	44.0	46	22 7/8	1.3	1.5	2.8
23	47.9	46.5	48	23 5/8	1.4	1.4	2.8
24	50.0	48.9	50	24 1/2	1.4	1.4	2.8
Head = 0.8 ft. or 9 5/8 inches							
1	2.1	....	2	1 5/8	0.1	6.6	6.7
2	4.2	2.6	4	2 3/4	0.3	6.6	6.9
3	6.3	4.4	6	3 7/8	0.4	6.5	6.9
4	8.3	6.3	8	4 7/8	0.6	6.5	7.1
5	10.4	8.2	10	6	0.7	6.5	7.2
6	12.5	10.1	12	7	0.9	6.4	7.3
7	14.6	12.0	15	8 1/2	1.1	6.4	7.5
8	16.7	14.0	17	9 1/2	1.3	6.3	7.6
9	18.8	16.0	19	10 1/2	1.5	6.2	7.7
10	20.8	18.1	21	11 3/8	1.6	6.2	7.8
11	22.9	20.0	23	12 3/8	1.8	6.1	7.9
12	25.0	22.1	25	13 1/2	2.0	6.0	8.0
13	27.1	24.1	27	14 3/8	2.2	5.9	8.1
14	29.2	26.2	29	15 1/4	2.3	5.8	8.1
15	31.2	28.3	31	16 1/4	2.5	5.7	8.2
16	33.4	30.5	33	17 1/8	2.7	5.5	8.2
17	35.4	32.8	35	18	2.9	5.4	8.3
18	37.5	35.0	38	19 1/4	3.1	5.2	8.3
19	39.6	37.3	40	20 1/4	3.3	5.0	8.3
20	41.7	39.6	42	21 1/8	3.5	4.8	8.3
21	43.8	41.9	44	21 7/8	3.6	4.6	8.2
22	45.8	44.1	46	22 3/4	3.8	4.4	8.2
23	47.9	46.5	48	23 1/2	3.9	4.3	8.2
24	50.0	48.8	50	24 3/8	4.1	4.1	8.2

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TABLE XIV

For Divisor Box Shown in Figure 4
Short box; floor flush with top of 4-inch dam;
divisor board hinged 24 inches from side of flume;
0.1 ft. or 1 3-16 inches effective head in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	....	2	3⅜	0.1	2.2	2.3
2	4.2	....	4	4⅞	0.1	2.2	2.3
3	6.3	1.0	6	6⅛	0.2	2.2	2.4
4	8.3	2.6	8	7⅜	0.2	2.2	2.4
5	10.4	4.2	10	8½	0.3	2.1	2.4
6	12.5	5.8	12	9½	0.3	2.1	2.4
7	14.6	7.4	15	11	0.4	2.0	2.4
8	16.7	9.2	17	12	0.4	2.0	2.4
9	18.8	11.1	19	12⅞	0.5	1.9	2.4
10	20.8	13.0	21	13¾	0.5	1.9	2.4
11	22.9	15.0	23	14¾	0.6	1.8	2.4
12	25.0	17.1	25	15⅝	0.6	1.8	2.4
13	27.1	19.3	27	16⅝	0.6	1.8	2.4
14	29.2	21.4	29	17⅛	0.7	1.7	2.4
15	31.2	23.7	31	18	0.7	1.7	2.4
16	33.4	26.1	33	18⅞	0.8	1.6	2.4
17	35.4	28.5	35	19¾	0.8	1.6	2.4
18	37.5	31.0	38	20¾	0.9	1.5	2.4
19	39.6	33.4	40	21½	0.9	1.5	2.4
20	41.7	36.0	42	22¼	1.0	1.4	2.4
21	43.8	38.6	44	23	1.0	1.4	2.4
22	45.8	41.4	46	23¾	1.1	1.3	2.4
23	47.9	44.1	..	..	...	...	...
24	50.0	46.8	..	..	...	...	...
Head = 0.8 ft. or 9⅝ inches							
1	2.1	....	2	2	0.1	4.0	4.1
2	4.2	2.0	4	3⅛	0.2	4.0	4.2
3	6.3	3.8	6	4⅛	0.3	4.0	4.3
4	8.3	5.8	8	5¼	0.4	3.9	4.3
5	10.4	7.7	10	6¼	0.4	3.9	4.3
6	12.5	9.6	12	7¼	0.5	3.9	4.4
7	14.6	11.5	15	8⅞	0.7	3.8	4.5
8	16.7	13.4	17	9⅞	0.8	3.8	4.6
9	18.8	15.3	19	11	0.9	3.8	4.7
10	20.8	17.2	21	12	1.0	3.7	4.7
11	22.9	19.1	23	13⅛	1.1	3.7	4.8
12	25.0	21.0	25	14⅛	1.2	3.6	4.8

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TABLE XIV (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.8 ft. or 9⅝ inches							
13	27.1	22.8	27	15⅛	1.3	3.6	4.9
14	29.2	24.8	29	16¼	1.5	3.5	5.0
15	31.2	26.7	31	17¼	1.6	3.5	5.1
16	33.4	28.6	33	18¼	1.7	3.4	5.1
17	35.4	30.5	35	19¼	1.8	3.3	5.1
18	37.5	32.5	38	20¾	2.0	3.2	5.2
19	39.6	34.6	40	21¾	2.1	3.1	5.2
20	41.7	36.6	42	22⅝	2.2	3.1	5.3
21	43.8	38.6	44	23⅝	2.3	3.0	5.3
22	45.8	40.7	..	..	...	...	...
23	47.9	42.7	..	..	...	...	...
24	50.0	44.8	..	..	...	...	...

TABLE XV

For Divisor Box Shown in Figure 4
Short box; floor flush with top of 4-inch dam; divisor board hinged 24 inches from side of flume; free flow in main channel, and 0.1 ft. or 1 3-16 inch effective head on divisor channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	....	2	5⅞	0.1	2.6	2.7
2	4.2	....	4	7¼	0.1	2.6	2.7
3	6.3	....	6	8⅝	0.2	2.5	2.7
4	8.3	....	8	9½	0.2	2.4	2.6
5	10.4	....	10	10⅝	0.3	2.3	2.6
6	12.5	2.2	12	11⅝	0.3	2.3	2.6
7	14.6	3.6	15	13	0.4	2.2	2.6
8	16.7	5.3	17	14	0.4	2.2	2.6
9	18.8	7.0	19	14⅞	0.5	2.1	2.6
10	20.8	8.9	21	15⅝	0.5	2.1	2.6
11	22.9	10.8	23	16½	0.6	2.0	2.6
12	25.0	12.8	25	17⅜	0.6	2.0	2.6
13	27.1	15.0	27	18⅛	0.7	1.9	2.6
14	29.2	17.2	29	18⅞	0.7	1.9	2.6
15	31.2	19.4	31	19¾	0.8	1.8	2.6
16	33.4	21.7	33	20½	0.8	1.8	2.6
17	35.4	24.1	35	21¼	0.9	1.7	2.6
18	37.5	26.7	38	22¼	1.0	1.6	2.6

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TABLE XV (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
19	39.6	29.2	40	23	1.1	1.6	2.7
20	41.7	31.8	42	23⅝	1.1	1.6	2.7
21	43.8	34.5	44	24⅝	1.2	1.5	2.7
22	45.8	37.2	..	..	...	...	...
23	47.9	40.0	..	..	...	...	...
24	50.0	42.9	..	..	...	...	...
Head = 0.8 ft. or 9⅝ inches							
1	2.1	....	2	6⅞	0.2	6.5	6.7
2	4.2	....	4	8½	0.3	6.4	6.7
3	6.3	....	6	10	0.4	6.3	6.7
4	8.3	....	8	11½	0.5	6.2	6.7
5	10.4	....	10	12⅝	0.7	6.0	6.7
6	12.5	1.0	12	14⅛	0.8	5.9	6.7
7	14.6	2.1	15	15⅞	1.0	5.7	6.7
8	16.7	3.3	17	17	1.1	5.6	6.7
9	18.8	4.6	19	18⅛	1.3	5.4	6.7
10	20.8	6.0	21	19	1.4	5.3	6.7
11	22.9	7.4	23	20	1.5	5.1	6.6
12	25.0	8.8	25	20⅞	1.6	5.0	6.6
13	27.1	10.3	27	21¾	1.7	4.8	6.5
14	29.2	11.9	29	22⅝	1.9	4.6	6.5
15	31.2	13.5	31	23⅜	2.0	4.5	6.5
16	33.4	15.2	33	24¼	2.1	4.3	6.4
17	35.4	17.0	..	..	...	...	...
18	37.5	18.9	..	..	...	...	...

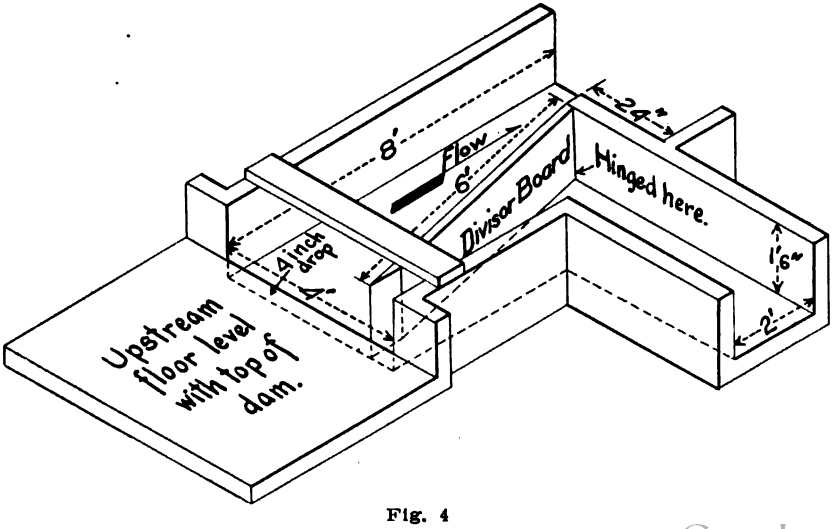

Fig. 4

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TABLE XV (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.8 ft. or 9⅝ inches							
19	39.6	20.9	..	..	...	...	...
20	41.7	23.0	..	..	...	...	...
21	43.8	25.2	..	..	...	...	...
22	45.8	27.5	..	..	...	...	...
23	47.9	30.0	..	..	...	...	...
24	50.0	32.5	..	..	...	...	...

TABLE XVI
For Divisor Box shown in Figure 4
Short box; floor flush with top of 4-inch dam;
Divisor board hinged 24 inches from side of flume; free flow in divisor channel and 0.1 ft. or 1 3-16 inches effective head in main channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	1.0	2	1⅛	0.1	2.4	2.5
2	4.2	3.0	4	2⅛	0.1	2.4	2.5
3	6.3	4.8	6	3⅝	0.2	2.3	2.5
4	8.3	6.7	8	4⅝	0.2	2.3	2.5
5	10.4	8.7	10	5⅝	0.3	2.2	2.5
6	12.5	10.8	12	6⅝	0.3	2.2	2.5
7	14.6	12.9	15	8	0.4	2.1	2.5
8	16.7	15.0	17	8⅞	0.4	2.1	2.5
9	18.8	17.3	19	9¾	0.5	2.0	2.5
10	20.8	19.6	21	10⅝	0.5	2.0	2.5
11	22.9	21.9	23	11⅝	0.6	1.9	2.5
12	25.0	24.3	25	12¼	0.6	1.9	2.5
13	27.1	26.7	27	13⅛	0.7	1.9	2.6
14	29.2	29.1	29	14	0.8	1.8	2.6
15	31.2	31.7	31	14¾	0.8	1.8	2.6
16	33.4	34.3	33	15½	0.9	1.7	2.6
17	35.4	36.8	35	16⅝	0.9	1.7	2.6
18	37.5	39.4	38	17½	1.0	1.6	2.6
19	39.6	42.0	40	18¼	1.0	1.6	2.6
20	41.7	44.8	42	19	1.1	1.5	2.6
21	43.8	47.6	44	19¾	1.2	1.4	2.6
22	45.8	50.5	46	20½	1.2	1.4	2.6
23	47.9	53.5	48	21⅛	1.3	1.4	2.7
24	50.0	56.5	50	21¾	1.3	1.3	2.6

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TABLE XVI (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.8 ft. or 9⅝ inches							
1	2.1	4.0	2	0⅛	0.1	4.1	4.2
2	4.2	7.7	4	1	0.2	4.0	4.2
3	6.3	11.3	6	1⅛	0.3	4.0	4.3
4	8.3	14.7	8	2⅛	0.4	4.0	4.4
5	10.4	17.9	10	2⅝	0.5	4.0	4.5
6	12.5	20.8	12	3¼	0.6	4.0	4.6
7	14.6	23.7	15	4⅛	0.7	4.0	4.7
8	16.7	26.4	17	4¾	0.8	3.9	4.7
9	18.8	29.1	19	5⅝	1.0	3.9	4.9
10	20.8	31.7	21	6	1.1	3.9	5.0
11	22.9	34.2	23	6¾	1.2	3.9	5.1
12	25.0	36.7	25	7⅛	1.3	3.8	5.1
13	27.1	39.2	27	8¼	1.4	3.8	5.2
14	29.2	41.5	29	9	1.6	3.8	5.4
15	31.2	44.0	31	9¾	1.7	3.7	5.4
16	33.4	46.4	33	10⅛	1.8	3.7	5.5
17	35.4	48.7	35	11⅝	2.0	3.6	5.6
18	37.5	51.1	38	12⅛	2.2	3.6	5.8
19	39.6	53.2	40	13¼	2.3	3.5	5.8
20	41.7	55.4	42	14⅛	2.5	3.4	5.9
21	43.8	57.5	44	15	2.6	3.4	6.0
22	45.8	59.5	46	15⅞	2.8	3.3	6.1
23	47.9	61.5	48	16⅝	3.0	3.2	6.2
24	50.0	63.5	50	17⅛	3.1	3.1	6.2

TABLE XVII

For Divisor Box Shown in Figure 5
Short box; 4-inch dam; divisor board hinged
12 inches from side of flume; free flow in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.2 ft. or 2⅜ icnhes							
1	2.1	1.5	2	..	...	...	...
2	4.2	3.1	4	2⅛	0.1	1.1	1.2
3	6.3	4.9	6	3⅛	0.1	1.1	1.2
4	8.3	6.9	8	4⅛	0.1	1.1	1.2
5	10.4	9.0	10	5⅛	0.1	1.0	1.1
6	12.5	11.2	12	6⅝	0.1	1.0	1.1

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TABLE XVII (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.2 ft. or 2⅜ inches							
7	14.6	13.3	15	7⅝	0.2	1.0	1.2
8	16.7	15.4	17	8⅝	0.2	1.0	1.2
9	18.8	17.5	19	9⅝	0.2	0.9	1.1
10	20.8	19.6	21	10⅝	0.2	0.9	1.1
11	22.9	21.7	23	11⅝	0.3	0.9	1.2
12	25.0	23.8	..	..	...	...	...
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	1.0	2	1¾	0.1	3.3	3.4
2	4.2	2.3	4	3⅛	0.1	3.2	3.3
3	6.3	3.8	6	4¼	0.2	3.1	3.3
4	8.3	5.6	8	5¼	0.3	3.0	3.3
5	10.4	7.5	10	6¼	0.3	3.0	3.3
6	12.5	9.5	12	7¼	0.4	2.9	3.3
7	14.6	11.6	15	8⅝	0.5	2.8	3.3
8	16.7	13.7	17	9⅝	0.6	2.7	3.3
9	18.8	15.8	19	10½	0.6	2.7	3.3
10	20.8	17.9	21	11½	0.7	2.6	3.3
11	22.9	20.0	..	..	...	...	...
12	25.0	22.2	..	..	...	...	...
Head = 0.8 ft. or 9⅝ inches							
1	2.1	1.0	2	1⅞	0.2	8.5	8.7
2	4.2	2.1	4	3¼	0.4	8.3	8.7
3	6.3	3.6	6	4¼	0.6	8.1	8.7
4	8.3	5.4	8	5⅝	0.7	8.0	8.7
5	10.4	7.3	10	6⅝	0.9	7.8	8.7
6	12.5	9.3	12	7¼	1.0	7.7	8.7
7	14.6	11.3	15	8¾	1.3	7.4	8.7
8	16.7	13.5	17	9¾	1.5	7.2	8.7
9	18.8	15.6	19	10⅝	1.7	7.0	8.7
10	20.8	17.7	21	11½	1.8	6.9	8.7
11	22.9	19.8	..	..	...	...	...
12	25.0	22.0	..	..	...	...	...

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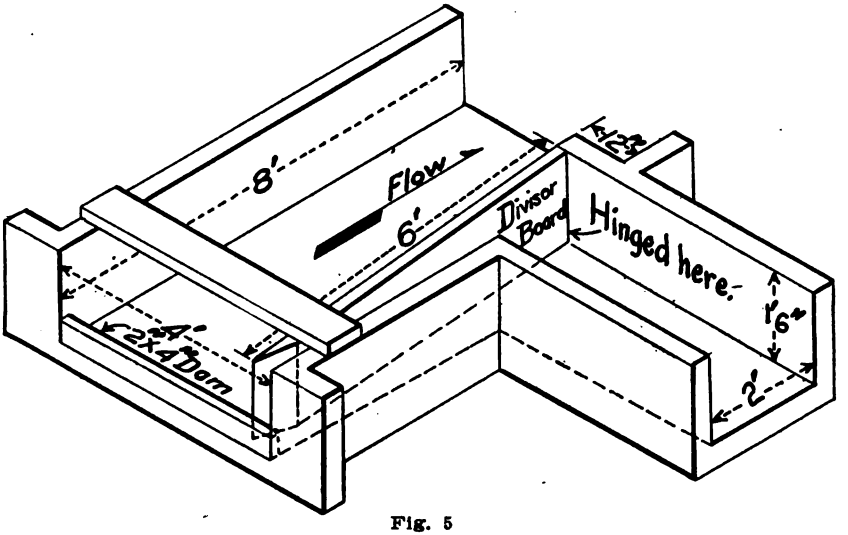

Fig. 5

TABLE XVIII

For Divisor Box Shown in Figure 5
Short box; 4-inch dam; divisor board hinged
12 inches from side of flume; 0.1 ft. or 1 3-16 inches
effective head in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	0.6	2	2⅜	0.1	2.5	2.6
2	4.2	1.6	4	3¾	0.1	2.5	2.6
3	6.3	2.9	6	4⅞	0.2	2.4	2.6
4	8.3	4.4	8	5⅞	0.2	2.4	2.6
5	10.4	6.3	10	6⅞	0.3	2.3	2.6
6	12.5	8.3	12	7¾	0.3	2.3	2.6
7	14.6	10.4	15	9⅛	0.4	2.2	2.6
8	16.7	12.6	17	10	0.5	2.1	2.6
9	18.8	14.8	19	10¾	0.5	2.1	2.6
10	20.8	17.1	21	11¾	0.6	2.0	2.6
11	22.9	19.4	..	..	...	...	...
12	25.0	21.7	..	..	...	...	...
Head = 0.8 ft. or 9⅝ inches							
1	2.1	0.8	2	2¼	0.1	5.2	5.3
2	4.2	1.8	4	3⅝	0.2	5.2	5.4
3	6.3	3.1	6	4⅝	0.3	5.2	5.5
4	8.3	4.7	8	5⅝	0.4	5.2	5.6
5	10.4	6.6	10	6⅝	0.6	5.1	5.7
6	12.5	8.7	12	7½	0.7	5.0	5.7

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TABLE XVIII (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow: Percent	Width of Divisor opening to give percentage of flow: Inches	Discharge in Second-feet: Divisor	Discharge in Second-feet: Channel	Discharge in Second-feet: Total
Head = 0.8 ft. or 9⅝ inches							
7	14.6	10.9	15	8⅝	0.8	4.9	5.7
8	16.7	13.2	17	9⅝	1.0	4.8	5.8
9	18.8	15.5	19	10½	1.1	4.7	5.8
10	20.8	17.9	21	11⅝	1.2	4.6	5.8
11	22.9	20.2	23	12⅛	1.3	4.4	5.7
12	25.0	22.6	..	..	...	...	...

TABLE XIX

For Divisor Box Shown in Figure 5
Short box; 4-inch dam; divisor board hinged
12 inches from side of flume; free flow in main channel;
0.1 ft. or 1 3-16 inches effective head in divisor channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow: Percent	Width of Divisor opening to give percentage of flow: Inches	Discharge in Second-feet: Divisor	Discharge in Second-feet: Channel	Discharge in Second-feet: Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	0.5	2	2⅝	0.1	3.2	3.3
2	4.2	1.3	4	4⅝	0.1	3.1	3.2
3	6.3	2.2	6	6⅛	0.2	3.0	3.2
4	8.3	3.2	8	7⅝	0.3	2.9	3.2
5	10.4	4.4	10	8½	0.3	2.8	3.1
6	12.5	5.8	12	9⅝	0.4	2.7	3.1
7	14.6	7.4	15	11¼	0.4	2.6	3.0
8	16.7	9.0	17	12⅝	0.5	2.5	3.0
9	18.8	10.8	..	..	...	...	...
10	20.8	12.6	..	..	...	...	...
11	22.9	14.4	..	..	...	...	...
12	25.0	16.4	..	..	...	...	...
Head = 0.8 ft. or 9⅝ inches							
1	2.1	....	2	5¼	0.2	7.8	8.0
2	4.2	0.5	4	7⅛	0.4	7.6	8.0
3	6.3	0.9	6	8⅝	0.5	7.5	8.0
4	8.3	1.4	8	9½	0.7	7.3	8.0
5	10.4	2.1	10	10½	0.8	7.1	7.9
6	12.5	2.9	12	11½	1.0	6.9	7.9
7	14.6	3.9	..	..	...	...	...
8	16.7	5.3	..	..	...	...	...
9	18.8	7.0	..	..	...	...	...
10	20.8	8.9	..	..	...	...	...
11	22.9	11.0	..	..	...	...	...
12	25.0	13.2	.	..	...	...	...

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TABLE XX

For Divisor Box Shown in Figure 5
Short box; 4-inch dam; divisor board hinged
12 inches from side of flume; free flow in divisor channel;
0.1 ft. or 1 3-16 inches effective head in main channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	2.4	2	..	...	...	...
2	4.2	4.7	4	1 3/4	0.1	2.5	2.6
3	6.3	7.1	6	2 1/2	0.1	2.5	2.6
4	8.3	9.5	8	3 3/8	0.2	2.4	2.6
5	10.4	11.9	10	4 1/4	0.3	2.4	2.7
6	12.5	14.3	12	5	0.3	2.4	2.7
7	14.6	16.8	15	6 1/4	0.4	2.3	2.7
8	16.7	19.2	17	7 1/8	0.4	2.3	2.7
9	18.8	21.6	19	7 7/8	0.5	22	2.7
10	20.8	24.0	21	8 3/4	0.6	2.2	2.8
11	22.9	26.3	23	9 5/8	0.6	2.2	2.8
12	25.0	28.7	25	10 1/2	0.7	2.1	2.8
Head = 0.8 ft. or 9 5/8 inches							
1	2.1	3.0	2	..	...	...	...
2	4.2	5.9	4	1 5/8	0.2	5.2	5.4
3	6.3	8.7	6	2	0.3	5.2	5.5
4	8.3	11.4	8	2 3/4	0.5	5.2	5.7
5	10.4	14.1	10	3 1/2	0.6	5.2	5.8
6	12.5	16.8	12	4 1/4	0.7	5.2	5.9
7	14.6	19.5	15	5 5/8	0.9	5.2	6.1
8	16.7	22.1	17	6 1/8	1.0	5.1	6.1
9	18.8	24.6	19	6 7/8	1.2	5.1	6.3
10	20.8	27.1	21	7 5/8	1.3	5.0	6.3
11	22.9	29.6	23	8 3/8	1.4	5.0	6.4
12	25.0	32.0	25	9 1/8	1.6	4.9	6.5

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TABLE XXI

For Divisor Box Shown in Figure 5*
Short box; 6-inch dam; divisor board hinged
12 inches from side of flume; free flow in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
			Head = 0.2 ft. or 2⅜ inches				
1	2.1	1.5	2	..	...	...	...
2	4.2	3.2	4	..	...	...	...
3	6.3	5.1	6	3½	0.1	1.1	1.2
4	8.3	7.1	8	4⅝	0.1	1.1	1.2
5	10.4	9.2	10	5⅝	0.1	1.1	1.2
6	12.5	11.4	12.	6¼	0.1	1.1	1.2
7	14.6	13.6	15	7⅝	0.2	1.0	1.2
8	16.7	15.8	17	8½	0.2	1.0	1.2
9	18.8	18.0	19	9½	0.2	0.9	1.1
10	20.8	20.2	21	10⅝	0.2	0.9	1.1
11	22.9	22.4	23	11¼	0.2	0.9	1.1
12	25.0	24.6	25	12¼	0.3	0.8	1.1
			Head = 0.4 ft. or 4 13-16 inches				
1	2.1	1.3	2	1⅛	0.1	3.2	3.3
2	4.2	2.7	4	2¾	0.1	3.2	3.3
3	6.3	4.3	6	3⅞	0.2	3.1	3.3
4	8.3	6.2	8	4⅞	0.3	3.0	3.3
5	10.4	8.2	10	5⅞	0.3	3.0	3.3
6	12.5	10.2	12	6⅞	0.4	2.9	3.3
7	14.6	12.3	15	8¼	0.5	2.8	3.3
8	16.7	14.4	17	9¼	0.6	2.7	3.3
9	18.8	16.5	19	10⅛	0.6	2.7	3.3
10	20.8	18.7	21	11⅛	0.7	2.6	3.3
11	22.9	20.8	23	12	0.8	2.5	3.3
12	25.0	23.0	..	..	...	...	...
			Head = 0.6 ft. or 7 3-16 inches				
1	2.1	1.2	2	1⅝	0.1	5.9	6.0
2	4.2	2.5	4	3	0.3	5.7	6.0
3	6.3	4.1	6	4⅛	0.4	5.6	6.0
4	8.3	5.8	8	5⅛	0.5	5.4	5.9
5	10.4	7.8	10	6⅛	0.6	5.3	5.9
6	12.5	9.8	12	7	0.7	5.2	5.9
7	14.6	11.9	15	8½	0.9	5.0	5.9
8	16.7	14.0	17	9⅝	1.1	4.9	6.0
9	18.8	16.1	19	10⅝	1.2	4.8	6.0
10	20.8	18.3	21	11¼	1.4	4.6	6.0
11	22.9	20.4	23	12¼	1.5	4.5	6.0
12	25.0	22.6	..	..	...	...	...

*Figure 5 applies, except for 6-inch dam instead of 4-inch dam as shown.

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TABLE XXII

For Divisor Box Shown in Figure 6
Short box; floor flush with top of 4-inch dam;
divisor board hinged 12 inches from side of flume;
free flow in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
			Head = 0.2 ft. or 2⅜ inches				
1	2.1	0.6	..	..	...	...	...
2	4.2	1.6	4	3⅞	0.1	0.9	1.0
3	6.3	2.8	6	5⅛	0.1	0.9	1.0
4	8.3	4.2	8	6¼	0.1	0.9	1.0
5	10.4	5.8	10	7⅜	0.1	0.9	1.0
6	12.5	7.6	12	8⅝	0.1	0.9	1.0
7	14.6	9.4	15	9¾	0.1	0.9	1.0
8	16.7	11.3	17	10⅝	0.2	0.8	1.0
9	18.8	13.4	19	11½	0.2	0.8	1.0
10	20.8	15.6	..	..	...	...	...
11	22.9	17.9	..	..	...	...	...
12	25.0	20.2	..	..	...	...	...
			Head = 0.4 ft. or 4 13-16 inches				
1	2.1	0.5	2	2¾	0.1	2.8	2.9
2	4.2	1.3	4	4⅜	0.1	2.8	2.9
3	6.3	2.3	6	5⅝	0.2	2.7	2.9
4	8.3	3.5	8	6¾	0.2	2.7	2.9
5	10.4	5.0	10	7¾	0.3	2.6	2.9
6	12.5	6.7	12	8¾	0.3	2.5	2.8
7	14.6	8.6	15	10	0.4	2.4	2.8
8	16.7	10.6	17	10⅞	0.5	2.3	2.8
9	18.8	12.7	19	11¾	0.5	2.3	2.8
10	20.8	15.0	..	..	...	...	...
11	22.9	17.4	..	..	...	...	...
12	25.0	19.8	..	..	...	...	...
			Head = 0.8 ft. or 9⅝ inches				
1	2.1	0.3	2	3¼	0.2	7.9	8.1
2	4.2	0.8	4	4¾	0.4	7.7	8.1
3	6.3	1.7	6	5⅞	0.6	7.5	8.1
4	8.3	2.9	8	6⅞	0.7	7.4	8.1
5	10.4	4.5	10	7¾	0.9	7.2	8.1
6	12.5	6.3	12	8¾	1.0	7.1	8.1
7	14.6	8.3	15	10	1.3	6.8	8.1
8	16.7	10.4	17	10¾	1.4	6.7	8.1
9	18.8	12.7	19	11⅝	1.6	6.5	8.1
10	20.8	15.0	..	..	...	...	...
11	22.9	17.5	..	..	...	...	...
12	25.0	20.0	..	..	...	...	...

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TABLE XXIII

For Divisor Box Shown in Figure 6
Short box; floor flush with top of 4-inch dam;
divisor board hinged 12 inches from side of flume;
0.1 ft. or 1 3-16 inch effective head in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	....	2	3⅝	0.1	2.3	2.4
2	4.2	0.8	4	5⅝	0.1	2.3	2.4
3	6.3	1.5	6	6⅝	0.2	2.2	2.4
4	8.3	2.4	8	7¾	0.2	2.2	2.4
5	10.4	3.6	10	8¾	0.2	2.2	2.4
6	12.5	5.0	12	9⅝	0.3	2.1	2.4
7	14.6	6.6	15	11	0.4	2.1	2.5
8	16.7	8.5	17	11¾	0.4	2.1	2.5
9	18.8	10.5	..	..	...	...	...
10	20.8	12.7	..	..	...	...	...
11	22.9	15.1	..	..	...	...	...
12	25.0	17.5	..	..	...	...	...
Head = 0.8 ft. or 9⅝ inches							
1	2.1	1.0	2	2⅛	0.1	5.1	5.2
2	4.2	1.9	4	3⅞	0.2	5.0	5.2
3	6.3	2.9	6	5⅝	0.3	4.9	5.2
4	8.3	4.1	8	6⅝	0.4	4.9	5.3
5	10.4	5.5	10	7⅞	0.5	4.8	5.3
6	12.5	6.9	12	8⅞	0.6	4.7	5.3

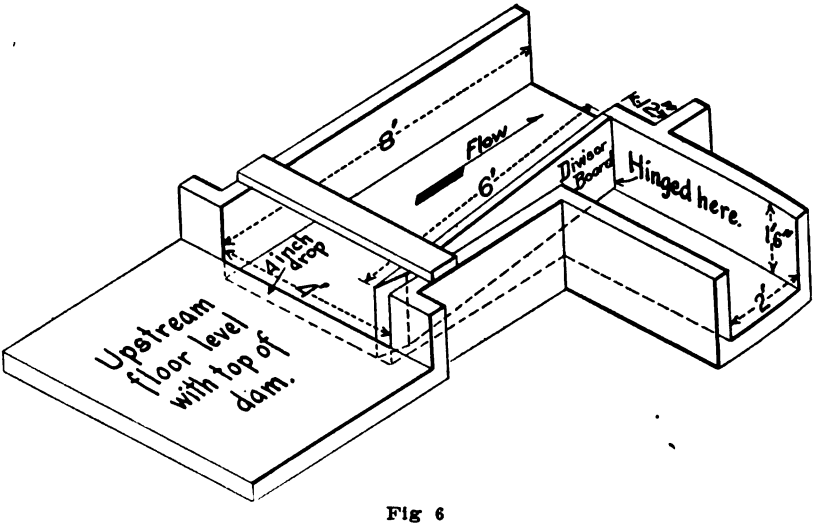

Fig 6

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TABLE XXIII (Continued)

Divisor opening in inches	Percent divisor flow is of total flow in box of box	Percent divisor opening is of total width	Width of Divisor opening to give percentage of flow: Percent	Width of Divisor opening to give percentage of flow: Inches	Discharge in Second-feet: Divisor	Discharge in Second-feet: Channel	Discharge in Second-feet: Total
			Head = 0.8 ft. or 9⅝ inches				
7	14.6	8.6	15	10⅝	0.8	4.5	5.3
8	16.7	10.4	17	11¼	0.9	4.4	5.3
9	18.8	12.3	19	12¼	1.0	4.3	5.3
10	20.8	14.3	..	..	...	...	...
11	22.9	16.4	..	..	...	...	...
12	25.0	18.5	..	..	...	...	...

TABLE XXIV

For Divisor Box Shown in Figure 6
Short box; floor flush with top of 4-inch dam;
divisor board hinged 12 inches from side of flume;
free flow in main channel;
0.1 ft. or 1 3-16 inch effective head in divisor channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow: Percent	Width of Divisor opening to give percentage of flow: Inches	Discharge in Second-feet: Divisor	Discharge in Second-feet: Channel	Discharge in Second-feet: Total
			Head = 0.4 ft. or 4 13-16 inches				
1	2.1	....	2	3⅝	0.1	2.7	2.8
2	4.2	....	4	5⅝	0.1	2.7	2.8
3	6.3	....	6	7⅝	0.2	2.6	2.8
4	8.3	2.3	8	8⅝	0.2	2.5	2.7
5	10.4	3.2	10	9⅞	0.3	2.4	2.7
6	12.5	4.3	12	11	0.3	2.3	2.6
7	14.6	5.6	15	12⅝	0.4	2.2	2.6
8	16.7	6.9	..	..	...	...	...
9	18.8	8.5	..	..	...	...	...
10	20.8	10.1	..	..	...	...	...
11	22.9	11.9	..	..	...	...	...
12	25.0	13.8	..	..	...	...	...
			Head = 0.8 ft. or 9⅝ inches				
1	2.1	....	2	5⅝	0.2	7.5	7.7
2	4.2	....	4	8	0.3	7.1	7.4
3	6.3	....	6	9⅞	0.5	6.8	7.3
4	8.3	1.1	8	11⅜	0.6	6.5	7.1
5	10.4	1.6	10	12⅝	0.7	6.2	6.9
6	12.5	2.3	..	..	...	...	...
7	14.6	3.1	..	..	...	...	...
8	16.7	4.0	..	..	...	...	...
9	18.8	5.0	..	..	...	...	...
10	20.8	6.1	..	..	...	...	...
11	22.9	7.5	..	..	...	...	...
12	25.0	8.9	..	..	...	...	...

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TABLE XXV

For Divisor Box Shown in Figure 6
Short box; floor flush with top of 4-inch dam;
divisor board hinged 12 inches from side of flume;
free flow in divisor channel;
0.1 ft. or 1 3-16 inch effective head in main channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	1.0	..	..	...	...	...
2	4.2	2.4	4	3 1/8	0.1	2.5	2.6
3	6.3	3.8	6	4 5/8	0.1	2.5	2.6
4	8.3	5.4	8	5 5/8	0.2	2.4	2.6
5	10.4	7.3	10	6 1/4	0.2	2.4	2.6
6	12.5	9.4	12	7 1/2	0.3	2.4	2.7
7	14.6	11.6	15	8 5/8	0.4	2.3	2.7
8	16.7	14.0	17	9 1/4	0.4	2.2	2.6
9	18.8	16.4	19	10	0.5	2.1	2.6
10	20.8	18.9	21	10 3/4	0.5	2.1	2.6
11	22.9	21.5	23	11 1/2	0.6	2.0	2.6
12	25.0	24.2	..	..	...	...	...
Head = 0.8 ft. or 9 5/8 inches							
1	2.1	2.5	2	0 3/4	0.1	5.3	5.4
2	4.2	5.0	4	1 5/8	0.2	5.2	5.4
3	6.3	7.5	6	2 5/8	0.3	5.2	5.5
4	8.3	10.0	8	3 1/4	0.5	5.2	5.7
5	10.4	12.5	10	4	0.6	5.1	5.7
6	12.5	15.1	12	4 3/4	0.7	5.1	5.8
7	14.6	17.6	15	6	0.9	5.0	5.9
8	16.7	20.2	17	6 3/4	1.0	4.9	5.9
9	18.8	22.7	19	7 1/2	1.1	4.9	6.0
10	20.8	25.3	21	8 1/4	1.3	4.8	6.1
11	22.9	27.9	23	9 1/8	1.4	4.8	6.2
12	25.0	30.5	25	9 7/8	1.6	4.7	6.3

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TABLE XXVI

For Divisor Box Shown in Figure 7
Short box; floor flush with top of 4-inch dam;
divisor board parallel to side of flume;
free flow in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
			Head = 0.2 ft. or 2⅜ inches				
1	2.1	0.5	2	2¾	...	...	...
2	4.2	1.3	4	4¼	...	...	...
3	6.3	2.3	6	5⅝	0.1	0.9	1.0
4	8.3	3.6	8	6⅞	0.1	0.9	1.0
5	10.4	5.3	10	7⅝	0.1	0.9	1.0
6	12.5	7.2	12	8⅝	0.1	0.9	1.0
7	14.6	9.1	15	9¾	0.1	0.9	1.0
8	16.7	11.2	17	10⅝	0.2	0.8	1.0
9	18.8	13.3	19	11½	0.2	0.8	1.0
10	20.8	15.6	21	12⅜	0.2	0.8	1.0
11	22.9	17.9	23	13¼	0.2	0.8	1.0
12	25.0	20.2	25	14	0.3	0.7	1.0
13	27.1	22.5	27	14⅞	0.3	0.7	1.0
14	29.2	24.9	29	15¾	0.3	0.7	1.0
15	31.2	27.3	31	16½	0.3	0.7	1.0
16	33.4	29.7	33	17⅜	0.3	0.7	1.0
17	35.4	32.1	35	18¼	0.4	0.6	1.0
18	37.5	34.5	38	19½	0.4	0.6	1.0
			Head = 0.4 ft. or 4 13-16 inches				
1	2.1	0.4	2	2⅞	0.1	2.7	2.8
2	4.2	1.1	4	4⅝	0.1	2.7	2.8
3	6.3	2.2	6	5½	0.2	2.6	2.8
4	8.3	3.5	8	6½	0.2	2.6	2.8
5	10.4	5.1	10	7⅝	0.3	2.5	2.8
6	12.5	6.9	12	8½	0.3	2.5	2.8
7	14.6	8.8	15	9⅞	0.4	2.4	2.8
8	16.7	10.9	17	10¾	0.5	2.3	2.8
9	18.8	13.0	19	11⅝	0.5	2.3	2.8
10	20.8	15.3	21	12½	0.6	2.2	2.8
11	22.9	17.6	23	13⅜	0.6	2.2	2.8
12	25.0	19.9	25	14¼	0.7	2.1	2.8
13	27.1	22.2	27	15	0.8	2.0	2.8
14	29.2	24.5	29	15⅞	0.8	2.0	2.8
15	31.2	26.8	31	16¾	0.9	1.9	2.8
16	33.4	29.2	33	17⅝	0.9	1.9	2.8
17	35.4	31.6	35	18⅝	1.0	1.9	2.9
18	37.5	34.1	38	19⅝	1.1	1.8	2.9

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TABLE XXVI (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.6 ft. or 7 3-16 inches							
1	2.1	0.8	2	3 1/8	0.1	5.1	5.2
2	4.2	0.8	4	4 1/2	0.2	5.0	5.2
3	6.3	1.9	6	5 5/8	0.3	4.9	5.2
4	8.3	3.2	8	6 5/8	0.4	4.8	5.2
5	10.4	4.8	10	7 3/4	0.5	4.7	5.2
6	12.5	6.7	12	8 5/8	0.6	4.6	5.2
7	14.6	8.7	15	10	0.8	4.5	5.3
8	16.7	10.7	17	10 7/8	0.9	4.4	5.3
9	18.8	12.8	19	11 3/4	1.0	4.3	5.3
10	20.8	15.0	21	12 5/8	1.1	4.2	5.3
11	22.9	17.3	23	13 1/2	1.2	4.1	5.3
12	25.0	19.6	25	14 3/8	1.3	4.0	5.3
13	27.1	21.9	27	15 1/8	1.4	3.9	5.3
14	29.2	24.2	29	16	1.5	3.8	5.3
15	31.2	26.6	31	16 7/8	1.6	3.7	5.3
16	33.4	29.0	33	17 5/8	1.7	3.6	5.3
17	35.4	31.4	35	18 1/2	1.9	3.4	5.3
18	37.5	33.8	38	19 3/4	2.0	3.3	5.3
Head = 0.8 ft. or 9 5/8 inches							
1	2.1	0.1	2	3 1/4	0.2	7.9	8.1
2	4.2	0.7	4	4 5/8	0.4	7.7	8.1
3	6.3	1.6	6	5 3/4	0.5	7.6	8.1
4	8.3	2.9	8	6 7/8	0.7	7.4	8.1
5	10.4	4.6	10	7 3/4	0.9	7.2	8.1
6	12.5	6.4	12	8 3/4	1.0	7.1	8.1
7	14.6	8.3	15	10 1/8	1.3	6.8	8.1
8	16.7	10.4	17	11	1.4	6.7	8.1
9	18.8	12.5	19	11 7/8	1.6	6.5	8.1
10	20.8	14.7	21	12 3/4	1.8	6.4	8.2
11	22.9	17.0	23	13 5/8	2.0	6.2	8.2
12	25.0	19.3	25	14 1/2	2.1	6.1	8.2
13	27.1	21.6	27	15 1/4	2.3	5.9	8.2
14	29.2	23.9	29	16 1/8	2.4	5.8	8.2
15	31.2	26.3	31	17	2.6	4.6	8.2
16	33.4	28.7	33	17 3/4	2.7	5.5	8.2
17	35.4	31.1	35	18 5/8	2.9	5.3	8.2
18	37.5	33.5	38	19 7/8	3.1	5.1	8.2

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TABLE XXVII

For Divisor Shown in Figure 7
Short box; floor flush with top of 4-inch dam;
divisor board parallel to side of flume;
0.1 ft. or 1 3-16 inches effective head in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	....	2	3⅝	0.1	2.4	2.5
2	4.2	0.5	4	5⅜	0.1	2.4	2.5
3	6.3	1.3	6	6½	0.2	2.3	2.5
4	8.3	2.4	8	7⅝	0.2	2.3	2.5
5	10.4	3.6	10	8⅝	0.2	2.2	2.4
6	12.5	5.0	12	9½	0.3	2.1	2.4
7	14.6	6.9	15	10⅞	0.3	2.1	2.4
8	16.7	8.9	17	11¾	0.4	2.0	2.4
9	18.8	10.9	19	12⅝	0.4	2.0	2.4
10	20.8	13.0	21	13⅝	0.5	1.9	2.4
11	22.9	15.2	23	14⅜	0.5	1.9	2.4
12	25.0	17.5	25	15¼	0.6	1.8	2.4
13	27.1	19.8	27	16⅛	0.6	1.8	2.4
14	29.2	22.0	29	17	0.7	1.7	2.4
15	31.2	24.3	31	17⅞	0.8	1.6	2.4
16	33.4	26.6	..	..	...	...	...
17	35.4	29.0	..	..	...	...	...
18	37.5	31.4	..	..	...	...	...
Head = 0.8 ft. or 9⅝ inches							
1	2.1	....	2	3¼	0.1	5.7	5.8
2	4.2	0.9	4	4¾	0.2	5.5	5.7
3	6.3	1.7	6	6	0.3	5.4	5.7
4	8.3	2.8	8	7⅛	0.4	5.2	5.6
5	10.4	4.3	10	8⅛	0.5	5.0	5.5
6	12.5	6.0	12	9	0.6	4.9	5.5
7	14.6	7.8	15	10⅝	0.8	4.7	5.5
8	16.7	9.9	17	11⅝	0.9	4.5	5.4
9	18.8	11.9	19	12¼	1.0	4.4	5.4
10	20.8	14.0	21	13⅛	1.1	4.3	5.4
11	22.9	16.2	23	14	1.2	4.1	5.3
12	25.0	18.4	25	14⅞	1.3	4.0	5.3
13	27.1	20.7	27	15¾	1.4	3.8	5.2
14	29.2	23.0	29	16⅝	1.5	3.7	5.2
15	31.2	25.3	31	17½	1.6	3.5	5.1
16	33.4	27.6	..	..	...	...	...
17	35.4	29.9	..	..	...	...	...
18	37.5	32.3	..	..	...	...	...

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TABLE XXVIII

For Divisor Shown in Figure 7
Short box; floor flush with top of 4-inch dam;
divisor board parallel to side of flume; free flow in main channel;
0.1 ft. or 1 3-16 inches effective head in divisor channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	0.6	2	..	...	...	...
2	4.2	1.2	4	5 1/8	0.1	2.6	2.7
3	6.3	1.9	6	7 3/8	0.2	2.5	2.7
4	8.3	2.7	8	8 7/8	0.2	2.5	2.7
5	10.4	3.5	10	10 1/8	0.3	2.4	2.7
6	12.5	4.5	12	11 1/8	0.3	2.3	2.6
7	14.6	5.6	15	12 5/8	0.4	2.2	2.6
8	16.7	6.8	17	13 1/2	0.4	2.2	2.6
9	18.8	8.2	19	14 1/2	0.5	2.1	2.6
10	20.8	9.8	21	15 5/8	0.5	2.1	2.6
11	22.9	11.7	23	16 5/8	0.6	2.0	2.6
12	25.0	13.7	25	17 1/4	0.7	1.9	2.6
13	27.1	15.8	27	18 1/4	0.7	1.9	2.6
14	29.2	17.9	..	..	...	...	...
15	31.2	20.1	..	..	...	...	...
16	33.4	22.3	..	..	...	...	...
17	35.4	24.5	..	..	...	...	...
18	37.5	26.7	..	..	...	...	...
Head = 0.8 ft. or 9 5/8 inches							
1	2.1	....	2	4 3/4	0.2	7.4	7.6
2	4.2	0.6	4	7 3/4	0.4	7.1	7.5
3	6.3	1.1	6	9 3/4	0.6	6.7	7.3
4	8.3	1.6	8	11 5/8	0.7	6.4	7.1
5	10.4	2.2	10	12 3/4	0.8	6.2	7.0
6	12.5	2.8	12	14	0.9	6.0	6.9
7	14.6	3.5	15	15 3/4	1.1	5.7	6.8
8	16.7	4.2	17	16 7/8	1.2	5.5	6.7
9	18.8	5.2	19	18	1.3	5.4	6.7
10	20.8	6.3	..	..	...	...	...
11	22.9	7.5	..	..	...	...	...
12	25.0	9.0	..	..	...	...	...
13	27.1	10.5	..	..	...	...	...
14	29.2	12.0	..	..	...	...	...
15	31.2	13.7	..	..	...	...	...
16	33.4	15.4	..	..	...	...	...
17	35.4	17.2	..	..	...	...	...
18	37.5	19.0	..	..	...	...	...

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TABLE XXIX

For Divisor Shown in Figure 7
Short box; floor flush with top of 4-inch dam;
divisor board parallel to side of flume;
free flow in divisor channel;
0.1 ft. or 1 3-16 inches effective head in main channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	1.1	..	..	...	...	...
2	4.2	2.4	4	3 1/8	0.1	2.5	2.6
3	6.3	3.8	6	4 5/8	0.2	2.4	2.6
4	8.3	5.3	8	5 5/8	0.2	2.4	2.6
5	10.4	7.1	10	6 5/8	0.3	2.3	2.6
6	12.5	9.2	12	7 1/4	0.3	2.3	2.6
7	14.6	11.6	15	8 5/8	0.4	2.2	2.6
8	16.7	14.1	17	9 1/8	0.4	2.2	2.6
9	18.8	16.6	19	9 7/8	0.5	2.1	2.6
10	20.8	19.2	21	10 3/4	0.5	2.1	2.6
11	22.9	21.7	23	11 1/2	0.6	2.0	2.6
12	25.0	24.2	25	12 3/8	0.7	1.9	2.6
13	27.1	26.7	27	13 1/8	0.7	1.9	2.6
14	29.2	29.3	29	13 7/8	0.8	1.8	2.6
15	31.2	31.9	31	14 5/8	0.8	1.8	2.6
16	33.4	34.5	33	15 5/8	0.9	1.7	2.6
17	35.4	37.0	35	16 1/4	0.9	1.7	2.6
18	37.5	39.6	38	17 5/8	1.0	1.6	2.6

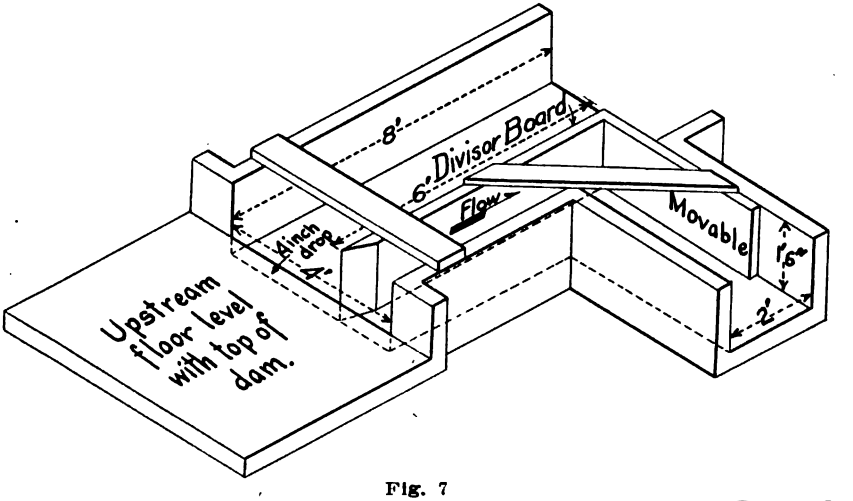

Fig. 7

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TABLE XXIX (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Divisor opening Width of to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.8 ft. or 9⅝ inches							
1	2.1	1.6	2	1¼	0.1	6.0	6.1
2	4.2	3.4	4	2¼	0.2	5.9	6.1
3	6.3	5.5	6	3¼	0.4	5.7	6.1
4	8.3	7.8	8	4	0.5	5.6	6.1
5	10.4	10.3	10	4⅞	0.6	5.5	6.1
6	12.5	13.1	12	5⅝	0.7	5.4	6.1
7	14.6	15.9	15	6⅝	0.9	5.3	6.2
8	16.7	18.7	17	7⅝	1.0	5.2	6.2
9	18.8	21.5	19	8	1.2	5.0	6.2
10	20.8	24.4	21	8¾	1.3	4.9	6.2
11	22.9	27.3	23	9½	1.5	4.8	6.3
12	25.0	30.2	25	10¼	1.6	4.7	6.3
13	27.1	33.1	27	10⅞	1.7	4.6	6.3
14	29.2	36.0	29	11⅝	1.9	4.5	6.4
15	31.2	38.9	31	12¼	2.0	4.4	6.4
16	33.4	41.8	33	13	2.1	4.3	6.4
17	35.4	44.7	35	13⅝	2.2	4.2	6.4
18	37.5	47.6	38	14¾	2.5	4.0	6.5

TABLE XXX

For Divisor Shown in Figure 8

Short box; no dam; divisor board parallel to side of flume; free flow in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.2 ft. or 2⅜ inches							
1	2.1	....	2	2⅜	0.1	0.8	0.9
2	4.2	1.2	4	3⅝	0.1	0.8	0.9
3	6.3	2.9	6	4⅝	0.1	0.8	0.9
4	8.3	4.6	8	5⅞	0.1	0.8	0.9
5	10.4	6.4	10	7	0.1	0.8	0.9
6	12.5	8.2	12	8	0.1	0.8	0.9
7	14.6	10.0	15	9½	0.1	0.8	0.9
8	16.7	12.0	17	10⅝	0.2	0.7	0.9
9	18.8	14.0	19	11⅝	0.2	0.7	0.9
10	20.8	16.1	21	12¼	0.2	0.7	0.9
11	22.9	18.2	23	13¼	0.2	0.7	0.9
12	25.0	20.4	25	14⅛	0.2	0.7	0.9

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TABLE XXX (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.2 ft. or 2⅜ inches							
13	27.1	22.6	27	15	0.2	0.7	0.9
14	29.2	24.8	29	15⅞	0.3	0.6	0.9
15	31.2	27.0	31	16¾	0.3	0.6	0.9
16	33.4	29.3	33	17⅝	0.3	0.6	0.9
17	35.4	31.6	35	18½	0.3	0.5	0.8
18	37.5	33.8	..	..	...	...	...
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	....	2	2¼	0.1	2.6	2.7
2	4.2	1.5	4	3⅛	0.1	2.6	2.7
3	6.3	3.1	6	4⅝	0.1	2.5	2.6
4	8.3	4.8	8	5¾	0.2	2.4	2.6
5	10.4	6.6	10	6¾	0.2	2.4	2.6
6	12.5	8.5	12	7⅞	0.3	2.3	2.6
7	14.6	10.4	15	9¼	0.4	2.2	2.6
8	16.7	12.4	17	10¼	0.4	2.2	2.6
9	18.8	14.4	19	11¼	0.5	2.1	2.6
10	20.8	16.4	21	12⅛	0.5	2.1	2.6
11	22.9	18.5	23	13	0.6	2.0	2.6
12	25.0	20.7	25	14	0.6	2.0	2.6
13	27.1	22.9	27	14⅞	0.7	1.9	2.6
14	29.2	25.1	29	15¾	0.7	1.9	2.6
15	31.2	27.3	31	16⅝	0.8	1.8	2.6
16	33.4	29.6	33	17½	0.9	1.7	2.6
17	35.4	31.9	35	18⅜	0.9	1.7	2.6
18	37.5	34.2	..	..	...	...	...
Head = 0.6 ft. or 7 3-16 inches							
1	2.1	....	2	2¼	0.1	4.9	5.0
2	4.2	1.6	4	3⅜	0.2	4.8	5.0
3	6.3	3.3	6	4½	0.3	4.7	5.0
4	8.3	5.1	8	5⅝	0.4	4.6	5.0
5	10.4	6.9	10	6⅝	0.5	4.5	5.0
6	12.5	8.7	12	7¾	0.6	4.4	5.0
7	14.6	10.6	15	9¼	0.8	4.2	5.0
8	16.7	12.6	17	10⅛	0.9	4.1	5.0
9	18.8	14.6	19	11⅛	1.0	4.0	5.0
10	20.8	16.7	21	12	1.1	3.9	5.0
11	22.9	18.8	23	12⅞	1.2	3.8	5.0
12	25.0	21.0	25	13⅞	1.3	3.7	5.0
13	27.1	23.2	27	14¾	1.4	3.6	5.0
14	29.2	25.4	29	15⅝	1.4	3.5	4.9
15	31.2	27.6	31	16½	1.5	3.4	4.9
16	33.4	29.8	33	17⅜	1.6	3.3	4.9
17	35.4	32.1	35	18¼	1.7	3.2	4.9
18	37.5	34.5	..	..	...	...	...

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TABLE XXX (Continued)

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
			Head = 0.8 ft. or 9⅝ inches				
1	2.1	....	2	2⅛	0.1	7.6	7.7
2	4.2	1.7	4	3¼	0.3	7.5	7.8
3	6.3	3.5	6	4⅜	0.4	7.4	7.8
4	8.3	5.3	8	5½	0.6	7.2	7.8
5	10.4	7.1	10	6½	0.8	7.0	7.8
6	12.5	9.0	12	7⅝	1.0	6.9	7.9
7	14.6	10.9	15	9	1.2	6.7	7.9
8	16.7	12.9	17	10	1.4	6.5	7.9
9	18.8	14.9	19	11	1.5	6.4	7.9
10	20.8	17.0	21	11⅞	1.7	6.2	7.9
11	22.9	19.1	23	12⅞	1.8	6.0	7.8
12	25.0	21.2	25	13¾	1.9	5.9	7.8
13	27.1	23.4	27	14⅝	2.1	5.7	7.8
14	29.2	25.6	29	15½	2.3	5.5	7.8
15	31.2	27.8	31	16⅝	2.4	5.4	7.8
16	33.4	30.0	33	17¼	2.6	5.2	7.8
17	35.4	32.3	35	18⅛	2.7	5.1	7.8
18	37.5	34.6	..	..	...	...	...
			Head = 1.0 ft. or 12 inches				
1	2.1	....	2	2⅛	0.2	10.8	11.0
2	4.2	1.8	4	3¼	0.4	10.5	10.9
3	6.3	3.6	6	4¼	0.6	10.3	10.9
4	8.3	5.4	8	5⅜	0.8	10.1	10.9
5	10.4	7.3	10	6⅜	1.0	9.9	10.9
6	12.5	9.2	12	7½	1.3	9.6	10.9
7	14.6	11.1	15	9	1.7	9.3	11.0
8	16.7	13.1	17	9⅞	1.9	9.1	11.0
9	18.8	15.1	19	10⅞	2.1	8.9	11.0
10	20.8	17.2	21	11¾	2.3	8.7	11.0
11	22.9	19.3	23	12¾	2.6	8.4	11.0
12	25.0	21.4	25	13⅝	2.8	8.2	11.0
13	27.1	23.6	27	14½	3.0	8.0	11.0
14	29.2	25.8	29	15⅝	3.2	7.8	11.0
15	31.2	28.0	31	16¼	3.4	7.6	11.0
16	33.4	30.3	33	17¼	3.6	7.3	10.9
17	35.4	32.6	35	18⅛	3.8	7.1	10.9
18	37.5	34.8	..	..	...	...	...

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TABLE XXXI

For Divisor Shown in Figure 8

Short box; no dam; divisor board parallel to side of flume;
0.1 ft. or 1 3-16 inches effective head in both channels

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	....	2	2 1/8	0.1	2.4	2.5
2	4.2	1.3	4	3 3/4	0.1	2.4	2.5
3	6.3	2.8	6	5	0.1	2.3	2.4
4	8.3	4.3	8	6 1/8	0.2	2.2	2.4
5	10.4	6.0	10	7 1/4	0.2	2.2	2.4
6	12.5	7.7	12	8 1/4	0.3	2.1	2.4
7	14.6	9.6	15	9 3/4	0.3	2.1	2.4
8	16.7	11.5	17	10 3/4	0.4	2.0	2.4
9	18.8	13.4	19	11 3/4	0.4	2.0	2.4
10	20.8	15.5	21	12 5/8	0.5	1.9	2.4
11	22.9	17.6	23	13 1/2	0.6	1.9	2.4
12	25.0	19.7	25	14 3/8	0.6	1.8	2.4
13	27.1	21.9	27	15 1/4	0.6	1.8	2.4
14	29.2	24.1	29	16 1/8	0.7	1.7	2.4
15	31.2	26.4	31	16 7/8	0.7	1.7	2.4
16	33.4	28.8	33	17 3/4	0.8	1.6	2.4
17	35.4	31.2	35	18 5/8	0.8	1.6	2.4
18	37.5	33.6	..	..	...	...	...
Head = 0.8 ft. or 9 5/8 inches							
1	2.1	....	..	..	...	...	...
2	4.2	1.4	4	3 5/8	0.2	5.6	5.8
3	6.3	3.1	6	4 3/4	0.4	5.4	5.8
4	8.3	4.8	8	5 7/8	0.5	5.3	5.8
5	10.4	6.5	10	6 7/8	0.6	5.2	5.8
6	12.5	8.3	12	7 7/8	0.7	5.1	5.8
7	14.6	10.2	15	9 5/8	0.9	4.9	5.8
8	16.7	12.2	17	10 5/8	1.0	4.8	5.8
9	18.8	14.2	19	11 1/4	1.1	4.7	5.8
10	20.8	16.2	21	12 1/4	1.2	4.6	5.8
11	22.9	18.3	23	13 1/8	1.3	4.5	5.8
12	25.0	20.5	25	14 1/8	1.5	4.4	5.9
13	27.1	22.7	27	15	1.6	4.3	5.9
14	29.2	24.9	29	15 7/8	1.7	4.2	5.9
15	31.2	27.1	31	16 3/4	1.8	4.1	5.9
16	33.4	29.3	33	17 5/8	1.9	4.0	5.9
17	35.4	31.5	35	18 5/8	2.1	3.8	5.9
18	37.5	33.7	..	..	...	...	...

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TABLE XXXII

For Divisor Shown in Figure 8
Short box; no dam; divisor board parallel to side of flume; free flow in main channel;
0.1 ft. or 1 3-16 inches effective head in divisor channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	....	2	2⅜	0.1	2.6	2.7
2	4.2	1.3	4	4	0.1	2.5	2.6
3	6.3	2.6	6	5⅝	0.2	2.4	2.6
4	8.3	3.9	8	6⅝	0.2	2.4	2.6
5	10.4	5.4	10	7¾	0.3	2.3	2.6
6	12.5	7.0	12	8¾	0.3	2.3	2.6
7	14.6	8.7	15	10¼	0.4	2.2	2.6
8	16.7	10.5	17	11¼	0.4	2.1	2.5
9	18.8	12.4	19	12¼	0.5	2.0	2.5
10	20.8	14.4	21	13⅛	0.5	2.0	2.5
11	22.9	16.5	23	14	0.6	1.9	2.5
12	25.0	18.6	25	15	0.6	1.9	2.5
13	27.1	20.7	27	15⅞	0.7	1.8	2.5
14	29.2	22.9	29	16¾	0.7	1.8	2.5
15	31.2	25.1	31	17½	0.8	1.7	2.5
16	33.4	27.4	..	..	...	...	...
17	35.4	29.8	..	..	...	...	...
18	37.5	32.2	..	..	...	...	...
Head = 0.8 ft. or 9⅝ inches							
1	2.1	....	2	3¼	0.1	7.4	7.5
2	4.2	0.7	4	4¾	0.3	7.2	7.5
3	6.3	1.8	6	6¼	0.5	7.0	7.5
4	8.3	3.0	8	7½	0.6	6.8	7.4
5	10.4	4.3	10	8¾	0.7	6.6	7.3
6	12.5	5.7	12	10	0.9	6.4	7.3
7	14.6	7.2	15	11⅝	1.1	6.1	7.2
8	16.7	8.8	17	12¾	1.2	5.9	7.1
9	18.8	10.4	19	13¾	1.4	5.7	7.1
10	20.8	12.1	21	14¾	1.5	5.6	7.1
11	22.9	13.8	23	15¾	1.6	5.4	7.0
12	25.0	15.6	25	16⅝	1.7	5.3	7.0
13	27.1	17.5	27	17⅝	1.9	5.1	7.0
14	29.2	19.5	29	18½	2.0	4.9	6.9
15	31.2	21.6	..	..	...	...	...
16	33.4	23.7	..	..	...	...	...
17	35.4	25.9	..	..	...	...	...
18	37.5	28.1	..	..	...	...	...

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TABLE XXXIII

For Divisor Shown in Figure 8

Short box; no dam; divisor board parallel to side of flume; free flow in divisor channel; 0.1 ft. or 1 3-16 inches effective head in main channel

Divisor opening in inches	Percent divisor opening is of total width of box	Percent divisor flow is of total flow in box	Width of Divisor opening to give percentage of flow		Discharge in Second-feet		
			Percent	Inches	Divisor	Channel	Total
Head = 0.4 ft. or 4 13-16 inches							
1	2.1	....	2	2 1/4	0.1	2.4	2.5
2	4.2	1.7	4	3 5/8	0.1	2.4	2.5
3	6.3	3.4	6	4 1/2	0.2	2.3	2.5
4	8.3	5.3	8	5 1/2	0.2	2.3	2.5
5	10.4	7.2	10	6 1/2	0.3	2.2	2.5
6	12.5	9.1	12	7 1/2	0.3	2.2	2.5
7	14.6	11.0	15	9	0.4	2.1	2.5
8	16.7	13.0	17	9 7/8	0.4	2.1	2.5
9	18.8	15.1	19	10 3/4	0.5	2.0	2.5
10	20.8	17.3	21	11 5/8	0.5	2.0	2.5
11	22.9	19.5	23	12 1/2	0.6	1.9	2.5
12	25.0	21.7	25	13 3/8	0.6	1.9	2.5
13	27.1	24.0	27	14 1/4	0.7	1.8	2.5
14	29.2	26.3	29	15 1/8	0.7	1.8	2.5
15	31.2	28.7	31	16	0.8	1.7	2.5
16	33.4	31.1	33	16 3/4	0.8	1.7	2.5
17	35.4	33.6	35	17 5/8	0.9	1.6	2.5
18	37.5	36.1	..	..	...	...	...
Head = 0.8 ft. or 9 5/8 inches							
1	2.1	....	2	1 7/8	0.1	5.8	5.9
2	4.2	2.3	4	2 5/8	0.2	5.7	5.9
3	6.3	4.8	6	3 1/2	0.3	5.6	5.9
4	8.3	7.3	8	4 1/4	0.5	5.5	6.0
5	10.4	9.8	10	5 1/8	0.6	5.4	6.0
6	12.5	12.2	12	5 7/8	0.7	5.3	6.0
7	14.6	14.7	15	7 1/8	0.9	5.2	6.1
8	16.7	17.2	17	7 7/8	1.0	5.1	6.1
9	18.8	19.6	19	8 3/4	1.2	5.0	6.2
10	20.8	22.0	21	9 5/8	1.3	4.9	6.2
11	22.9	24.4	23	10 3/8	1.4	4.8	6.2
12	25.0	26.8	25	11 1/4	1.6	4.7	6.3
13	27.1	29.2	27	12 1/8	1.7	4.6	6.3
14	29.2	31.5	29	12 7/8	1.8	4.5	6.3
15	31.2	33.8	31	13 3/4	2.0	4.4	6.4
16	33.4	36.2	33	14 5/8	2.1	4.3	6.4
17	35.4	38.5	35	15 1/2	2.3	4.2	6.5
18	37.5	40.8	38	16 3/4	2.5	4.1	6.6
..	....	....	40	17 5/8	2.6	4.1	6.7

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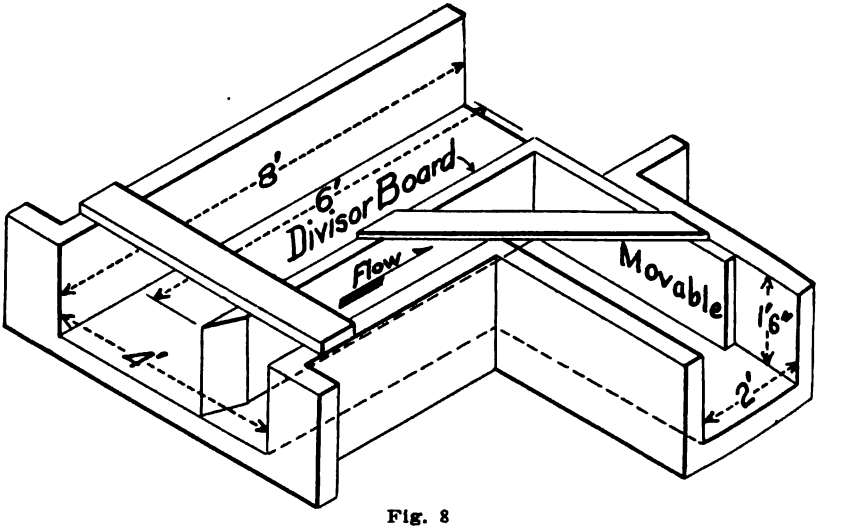

Fig. 8

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Bulletin 229 May, 1917

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

BRISKET DISEASE

(Bulletin No. 204 revised and abbreviated)

By

GEORGE H. GLOVER and I. E. NEWSOM

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1917

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This bull was raised at Golden, Colo., altitude 5,693 feet, shipped to South Park, where he was ranged between 11,000 and 12,000 feet. He developed the disease during the summer of 1914, was shipped to Denver and recovered within two weeks after arrival. No medicinal treatment was given.

A Shorthorn steer raised in Texas and sent to South Park a year previous to the development of the disease. Ranged at an altitude of between 11,000 and 12,000 feet. He was shipped to Denver, where he recovered in less than three weeks, without medicinal treatment.

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BRISKET DISEASE

(Bulletin No. 204 revised and abbreviated)

By
GEORGE H. GLOVER and I. E. NEWSOM

SUMMARY

A disease occurs in cattle in the high altitudes of Colorado, the principal symptoms of which are swelling of the brisket and of the loose tissues under the jaw, usually diarrhoea and a moist cough, with gradual emaciation and death. It is chronic in character but is fatal in practically all cases.

On autopsy the most marked features are generalized dropsy, enlarged and hard liver and dilated heart.

It appears to be caused by an exhaustion of the heart muscle associated with a varying degree of dilatation and hypertrophy, this being brought about by failure of acclimatization at high altitudes.

Medical treatment has so far proven of little avail, but, where possible, shipping the affected animals to a lower altitude is recommended.

Preventive measures include the use of bulls that have been raised at altitudes of 8,000 feet or more, with a view to building up a hardier strain of cattle; also the curtailment of indiscriminate shipping of low altitude cattle to high altitudes.

BRIEF FACTS HERE GIVEN

Bulletin No. 204 of this Station entitled "Brisket Disease" having become exhausted, it has seemed desirable to set down briefly such facts about the disease as will be of value to the stockmen of the State. The inquiries concerning this disease continue to come to the Station and it is to answer these in a more comprehensive manner than can be done by letter that this bulletin is prepared. The Station began its work on this malady in 1913 at the special request of many stockmen who had sustained loss of animals.

HISTORY AND DISTRIBUTION

Brisket disease has been known in Colorado since 1889 and since that time has caused an annual loss of approximately 1 per cent of all cattle maintained above an altitude of 8,000 feet. It has been especially prevalent in the high mountain parks. Practically every year numerous cases are seen in North, Middle and South Parks and on the forest reserves surrounding the same. It is a frequent cause of loss on nearly

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all of the forest reserves since these are usually found at high altitudes. It seems not to occur in the San Luis Valley to any extent, but is frequent on the ranges adjacent to that territory. In fact it has been seen in practically every part of the State where many cattle are maintained above an altitude of 8,000 feet.

The disease is known definitely to exist in Wyoming and New Mexico but so far has not been diagnosed in any other state or country. One report of its occurrence in Montana has not been verified. It is said by competent authority not to exist in the Alps of Switzerland.

ANIMALS AFFECTED

Cattle of all ages are susceptible, even calves as young as one month often showing well marked symptoms. In fact many calves die from the disease when the owners do not recognize the ailment.

CAUSE

It seems to have been demonstrated that the cause lies in failure of acclimatization to extreme altitudes. The malady is far more prevalent in animals that are shipped in from low altitudes. In the case of calves, those that are sired by low altitude bulls are much more susceptible. The higher the altitude the more prevalent is the disease and the shipping of affected animals to lower levels will in a majority of the cases effect a cure. All of these observations clearly indicate that the altitude is the chief factor. In order to eliminate the food as a factor the Station shipped six affected animals to Fort Collins (altitude 5,000 feet) and fed them on South Park hay after arrival. (This disease is very prevalent in South Park, altitude 9,000 to 10,000 feet.) Four of these animals recovered, while two died. Since the two which died arrived in a moribund condition, and one of them died within 24 hours after arrival, it is not believed the food could have been responsible for their death.

The disease does not appear to be contagious, since only a small percentage of animals is ordinarily affected. The work of the Station has never revealed a micro-organism that could in any way be a causative factor. Transmission experiments resulted negatively in the two instances tried.

It is the belief of those who have investigated the disease that the lack of oxygen, the exhausting labor involved in grazing over the mountains, and the severe climate, all result in over-strain of the heart in some individuals, which leads to the generalized dropsy that has been called brisket disease.

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SYMPTOMS

The first evidence of the disease is a dull, listless appearance, the hair stands on end and the ears droop. The animal appears gaunt owing to failure to take the usual amount of food. There may be a slight, moist cough. A diarrhoea usually appears soon after the other symptoms, or it may even be the first symptom noted. The respiration is increased and the pulse is rapid and weak. Many calves die in this stage without showing any swelling of the brisket. In some instances the appetite remains good up to within a few days of death.

Later, there appears a swelling of the loose tissue under the jaw and a swelling of the loose tissues of the brisket. Either swelling may appear first, but gradually the two merge into each other as the whole under part of the neck becomes dropsical. In male animals, the sheath may swell considerably and the hind limbs become puffy. The fore limbs may stock in extreme cases. The swelling of the brisket may become enormous in size, extending out in front of the fore limbs as a rather firm doughy mass. There is no pain on pressure and the part is not increased in temperature. The abdomen may swell markedly in its lower portion, due to accumulation of fluid.

The respiration becomes increased, but labored only on exercise. A clear, mucous discharge comes from the eyes and nostrils. There is no fever. The heart-beats are increased, especially on slight excitement or exercise, when they may run 100 to 120 per minute. Under these circumstances the beat is tumultous but lacks force, as evidenced by a very weak pulse. A pronounced jugular pulse is common in the later stages.

Forced exercise in this later stage will cause labored breathing, coughing, hemorrhage from the nose, and if continued, quick death. Consequently, it is difficult to drive an afflicted animal any considerable distance.

The animals become very weak, so that the slightest exertion or excitement causes them to fall. This has been noticed repeatedly when attempting to restrain them for close observation.

The usual course of the disease is from two weeks to three months, although a few animals have been known to apparently recover in the spring, only to be taken down again the following fall. We may say that most animals die within a month after symptoms are first noticed, the older cattle living longer than the younger. Death seems to be due either to suffocation or exhaustion and paralysis of the heart.

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LESIONS

The carcass is usually emaciated. The subcutaneous tissues in the region of the brisket, lower side of the neck, and under the jaw are infiltrated with a clear serum. It does not flow freely when incised, but can be squeezed out. Sometimes the subcutaneous tissue of the limbs is similarly affected.

When the abdomen is opened, a considerable quantity of straw-colored fluid escapes, sometimes as much as six or eight gallons.

The liver is always much enlarged and is tough, firm and leathery. On section it has a grayish mottled appearance, the cut veins being very large. The condition of the liver is very noticeable and seems to be constant.

In the thorax a large amount of fluid is to be found, as in the abdomen. The lungs are edematous. The heart is enlarged, dilated and usually flabby.

DIFFERENTIAL DIAGNOSIS

It simulates traumatic pericarditis, but can be differentiated by the fever which usually accompanies the latter disease. On post-mortem examination the finding of pus in the pericardium would eliminate brisket disease and point to traumatism.

It could easily be mistaken for pneumonia, especially if complicated with pleurisy, in which case the brisket might be swollen. The diagnosis of these latter conditions would be based on the presence of fever in the live animal and, on autopsy, signs of inflammation in the lungs and pleura.

TREATMENT

Of twelve animals shipped to a lower altitude under the direction of the Station, ten recovered, although no other treatment was administered. It is the belief of most stockmen who have had experience that getting the animals to a lower level is sufficient to effect a cure. It appears that taking the animals from the ranges around the San Luis Valley down into the Valley proper (altitude 7,500 feet) has effected a cure in many cases. Most of the animals that have been shipped from South Park to Denver (5,280 feet) have recovered. Consequently, removal to a lower altitude is always to be recommended if feasible. The difficulty comes in getting these animals to a shipping point, as they are so weak that they can be driven only with difficulty.

Medicinal treatment has always been unsatisfactory but can be tried if the animals can be put into a warm place. Any treatment on the range is believed to be out of the question.

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If the animals can be gotten to a place where they can receive daily care, then treatment should be tried as follows:

Keep them quiet, do not excite them any more than absolutely necessary. Give them plenty of water and hay, preferably alfalfa. Drench them daily with a teaspoonful of fluid extract of digitalis for adult animals and ten drops for young calves. The medicine can be put into a few ounces of water. This treatment can be kept up for two or three weeks, when it should be discontinued for a time. This suggested treatment is not given with the expectation that many animals will be saved by it, but only that it may be tried where it is impracticable to get the animals to a lower altitude. Such animals, even if they recover, should be shipped out at the first convenient opportunity.

PREVENTION

Since the disease is far more prevalent in cattle shipped in from low altitudes than in natives, it would seem only wise that importations be somewhat curtailed or, if practiced, that the animals be brought more gradually to the extreme altitudes.

Since extreme exertion on first arrival at the higher level seems to play a part, more care should be taken in the handling of the animals during the first few weeks to see that they are not subjected to long, hard drives. Realizing that these animals are usually wild, we are aware of the difficulty in complying with this suggestion.

The practice of buying pure-bred bulls from low altitudes, while praiseworthy in its intent, seems to be responsible for some of the difficulty. Not only do the bulls themselves in many instances die of the disease after some months residence under the new conditions, but their calves appear to be much more susceptible than calves sired by native bulls. In order to reduce this source of trouble it is recommended that bulls be purchased from altitudes more nearly approaching that at which they are to be used. We believe that this practice, if followed, would do much toward eliminating the disease. The idea is to breed a more vigorous animal that can stand the unusual conditions incident to a high altitude. Finally, it may become necessary to abandon some of the higher ranges, especially during cold and wet summers. Since the disease has not been seen in sheep, it may be possible to range these animals at the higher levels where the cattle do not thrive.

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The two animals pictured above were from a lot of 35 that were raised near Parker, Colorado. One is a four-year-old cow, the other a two-year-old steer. They were shipped to a ranch near Fairplay, Colorado (altitude 9,500 ft.) where they were ranged with about 50 native cattle. Six of the animals raised at Parker (altitude 6,000 ft.) became ill with brisket disease, while none of the natives were affected. These animals were seen on October 17, 1915, at which time they had been sick about three weeks. On this same date a six-months-old calf of the Parker lot born at the high altitude was found to be suffering from the same disease.

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Bulletin 230 July, 1917

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

THE WATERS OF THE RIO GRANDE

A Contribution to the Hydrology of the San Luis Valley, Colorado

By
WM. P. HEADDEN

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1917

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THE WATERS OF THE RIO GRANDE

By WM. P. HEADDEN

In Bulletin No. 82 of this station, "Colorado Irrigation Waters and Their Changes", I dealt with the waters of the eastern slope, treating those of the Poudre Valley in greater detail than the rest, for four reasons, the principal one being that irrigation has been practiced on a larger scale in this valley than in any other section of the State. Irrigation was practiced on a small scale in the San Luis Valley by the Mexicans earlier than by the settlers of the Poudre Valley, but this practice was by no means so extended as it has been in the Poudre Valley, from the time of its introduction.

The second reason for confining our study largely to the waters used in the Poudre Valley was the fact that we are situated within this territory and all parts of it; the streams, ditches and reservoirs, are easily accessible at all times. These reasons were formulated in the bulletin referred to as follows: **"The considerations which have led me to confine myself to the study of the Poudre River water to so great an extent as I have done, are evident. First, the water of the Poudre irrigates, at the present time, as much if not more land than that of any other stream in the State. Second, it flows through our home valley, is easy of access, and we have fuller data and more intimate knowledge of it than of any other stream in the State. Third, irrigation has been practiced in this valley as long as in any other part of the State (a few sections where irrigation was practiced by the Mexicans expected), extending over a period of 43 years. Fourth, the oldest, and at the same time an extensive system of reservoirs, whose beginning dates back to 1875, has been made to supplement the summer flow of the river.**

"Under these conditions the flow of the return waters has already been established, the first exaggerated effects of irrigating this land have passed away and the rate at which the return waters are carrying the soluble salts from the soil has presumably approached, if it has not already reached, the point at which it will remain for years to come. The same may be assumed to be true in regard to the character of the salts taken into solution.

"In this section, the period of drainage has begun, land having become valuable enough and water in such demand that drainage has already been instituted for the double purpose of preventing the land from being water-logged or seeped, and for rendering the water available for irrigating other land."

CHANGES IN WATERS OF EASTERN SLOPE

These paragraphs were written thirteen years ago and are as applicable now as then. The work done preparatory to the publication of Bulletin No. 82 made the changes which take place in the amount

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and character of the mineral constituents, held in solution by these waters upon their entrance into that part of their course which lies outside of the mountains very definite and showed that these changes were radical. The total solids increased from 2.9 and 2.6 grains per imperial gallon in samples taken within the mountain section of its course, to 114.5 grains in a sample taken perhaps thirty miles further down its course. The composition of the mass of salts had changed to even a greater degree than the amount of them held in solution. The reader may judge for himself how radical these changes are from the following statements of analytical results given in grains per imperial gallon:*

ANALYSES OF CACHE LA POUDRE WATER

I Taken within the mountains		II Taken about thirty miles out from the mountains	
Salts	Grains per imperial gal.	Salts	Grains per imperial gal.
Calcic sulfate	0 3417	Calcic sulfate	46.013
Calcic carbonate	0.7186	Magnesic sulfate	36.406
Magnesic carbonate	0 2628	Potassic sulfate	0.719
Sodic chlorid	0 1711	Sodic sulfate	6.059
Potassic carbonate	0 1254	Sodic chlorid	4.565
Sodic carbonate	0.2652	Sodic carbonate	14.337
Sodic silicate	0.2544	Sodic silicate	2.099
Ferric and Al. oxid	0.0113	Ferric and Al. oxids	0.079
Manganic oxid	0.0018	Manganic oxid	Trace
Excess silicic acid	0.0798	Excess sodic oxid	0.096
Ignition	(0.2678)	Ignition	4.191
Total	2.8999	Total	114.504

SANITARY ANALYSES

Taken within the mountains		Taken about thirty miles out from the mountains
Salts	Parts per Million	Parts per Million
Tota solids	41.4286	1,635.710
Chlorin	1.9804	36.630
Nitrogen as nitrates	Trace	0.400
Nitrogen as nitrites	None	0.022
Saline ammonia	0.0350	0.060
Albuminoidal ammonia	0.0900	0.160
Oxygen consumed	2.550	1.160

The total solids contained in this water had been increased approximately forty times, though it had reached a point only about 30 miles beyond the mountains. The carbonates which predominated in the mountain water have disappeared, with the exception of sodic

*I retain this old form of statement because I believe it to be, all things considered, more easily apprehended by the general reader than other forms often used. The imperial gallon, being an even ten pounds, is a convenient measure and the hypothetical compounds are, for the most part, familiar, at least by name, to the general reader. The scientific man will have no difficulty in accommodating himself to this mode of statement, even though he is accustomed to the really more simple and scientific ionic statement.

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carbonate, and in their place we find sulfates, with a very great increase in the amount of the bases present in this form. The total sodium present in various forms also has been increased very greatly.

The water of the Cache la Poudre is typical of all of our mountain streams in its composition and the changes in its composition due to its use in irrigating our lands are typical of those produced in the waters of other streams when used for this purpose. These changes have been studied for the Arkansas and the results justify the statement just made. The results obtained were:

ANALYSES OF ARKANSAS RIVER WATER

I

Taken at Canon City

Salts	Grains per imperial gallon
Calcic sulfate	2.037
Calcic carbonate	3.733
Magnesic carbonate	1.856
Potassic sulfate	0.138
Sodic chlorid	0.659
Sodic carbonate	0.573
Sodic silicate	1.280
Ferric & Alum. oxids.	0.023
Manganic oxid (br)	0.011
Excess Silicic acid	0.216
Ignition	0.273
Total	10.799

II

Taken about 120 miles below Canon City

Salts	Grains per imperial gallon
Calcic sulfate	64.942
Magnesic sulfate	27.994
Potassic sulfate	0.942
Sodic sulfate	32.449
Sodic chlorid	12.044
Sodic carbonate	7.007
Sodic silicate	1.358
Excess sodic oxid	3.832
Ignition	6.797
Total	157.363

SANITARY ANALYSIS

	Parts per million
Total solids	2,234.290
Chlorin	103.971
Nitrogen as nitrates	1.500
Nitrogen as nitrites	0.040
Saline ammonia	0.065
Albuminoidal ammonia	0.140
Oxygen consumed	2.000

This sample of Arkansas River water was taken at Canon City, a little way below the Royal Gorge, and while it carries more salts in solution than the Poudre water, it remains in its essential features a mountain water. This is more remarkable than the fact that it carries nearly four times as much solid matter in solution as the Poudre water, for the course of the Poudre River, up to the point where the sample was taken, is wholly within a granitic area, with but little meadow land along its borders and with an exceedingly sparse population.

The Arkansas at Canon City has already traversed a long course, some of the way through meadow lands. It received during a portion of the year the sluicings from placer workings and its drainage

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area includes the towns of Leadville, Buena Vista and Salida. The conditions, however, have not been such as to materially change the character of the water. The sample of water taken about 120 miles further down the stream, was wholly return water, namely, irrigating water that had been applied to the land and had found its way back into the river's course. At the time that this sample was taken, no river water was flowing past Rocky Ford, the point at which the sample was taken, for all of the river water had been diverted into the various irrigating canals or ditches. The differences shown in the two cases, those of the Poudre and Arkansas river waters, are wholly quantative; the changes shown are identical in kind.

The waters of the South Platte have been studied but to a less extent than those of the other streams. The conditions obtaining in this case are somewhat different from those obtaining in the cases of the Poudre and Arkansas. Still, the results obtained agree in showing that the changes produced in the character of the solids held in solution are the same as in the cases previously given.

These changes are thorough-going; in the mountain waters we have the carbonates of lime, magnesia and soda predominating, while in the return waters we have these changed to sulfates and the quantity of these salts very greatly increased—ten times in the case of the Arkansas and forty times in the case of the Poudre water.

These general statements evidently hold for the Laramie, for its waters are partly diverted into the Poudre without perceptible modification of the results. They will probably hold for all of the streams of our arid regions where the conditions are similar to those obtaining in these cases; but it is not safe to assert that they will hold for all of our streams.

CONDITIONS IN SAN LUIS VALLEY EXCEPTIONAL

We recognize, on examining the water conditions of the San Luis Valley, that they are exceptional. While the big features of the case may be very simple, there are others which are not, and the problem becomes, taken in its entirety, far more difficult to explain satisfactorily than those of the eastern slope, where our problems of natural drainage and return waters are quite simple, and the changes in the waters of our streams are really such as should be produced by the waters entering them after flowing through adjacent higher-lying lands whether under cultivation or not.

The Rio Grande enters the San Luis valley a little north of the middle of the west side and flows southeasterly and south to the state line. We shall consider it only as far as the State Bridge, a distance of about 60 miles.

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BED OF RIVER HIGHER THAN VALLEY

The river has built up its bed till it is higher than the valley. It does not matter to us when or how this has been done; the important fact is, that the present bed is higher than the adjacent territory. Under such condtions it may seem a perfectly simple matter that a river flowing over a pervious bottom should lose a considerable portion of its water and that none could flow into it, if these conditions prevail in all sections of its course. The annual discharge of the Rio Grande at the State Bridge, is about two-thirds of its discharge at Del Norte; or, in flowing about 60 miles, it loses one-third of its annual flow. There is no other visible outlet for the waters of the valley. The discharge at Embudo in New Mexico, however, is much greater than at the State Bridge, though the river receives no considerable visible streams in the intervening section. This last statement is made to avoid the plainly legitimate inference from the preceding statement that the valley is being filled with water by the Rio Grande. While the facts to be presented may appear at times to approach very near to this problem, it remains entirely beyond our purpose to discuss it. As stated, our problem would seem very simple, if its solution depended wholly upon the Rio Grande waters, which flow over a pervious bed higher than the surrounding country. Such waters should flow, as they actually do, for about 60 miles, over such a bed with small, almost insignificant changes in their composition.

In the beginning of this work we proposed to treat it as an extension of the work presented in Bulletin 82. This included ground and return-waters and had been preceded by a presentation of the composition of the soil, its water-soluble portion and of the ground-waters. While the water-soluble portion of the soil is not necessarily identical with our alkalis, it is so closely related to them that it seems useless to insist on the difference. While I disclaim any intention to discuss the water-supply questions of the valley and its drainage, the smaller questions suggested above cannot be avoided. It is true that these questions are subordinate to the geological question of the drainage of the valley, but they involve the questions pertaining to the river and well waters used for irrigation, the ground waters and the alkalis.

The waters used for irrigation in the San Luis Valley are, as in the Poudre Valley, essentially mountain waters, and I shall take the Rio Grande waters as typical of them, but I have no proper return-waters to present, and but few ground-waters.

The Rio Grande has no tributary entering it from the north, though the valley receives the waters from a very large mountain area at this end. I am credibly informed that the water flowing into the

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valley north of the Rio Grande aggregates 2,000 second-feet for several months during the year and a very considerable amount at all times. There is no doubt in regard to the source of the artesian waters found throughout a large portion of the valley. It is assumed to be from the streams flowing from the mountains, mostly from the north and west, and also from the east, but in a smaller measure. This artesian water has received attention from several writers as a supply for irrigation. I have made some inquiry and have failed to learn of its application for this purpose. It furnishes an excellent water supply for stock and perhaps for irrigating some small areas but I have no definite information of such excepting lawns. The ranches depend upon the ditches for their irrigating water. The Rio Grande, Conejos, and some other streams furnish the ditch water but of these the Rio Grande is by far the most important.

ANALYSES OF RIO GRANDE WATERS

The course of the Rio Grande extends many miles into the mountains west of the San Luis Valley. We did not go up the river further than just above the mouth of Willow Creek near the town of Creede. We took samples of the water from here down to the State Bridge. We present the analytical results in the order in which the samples were taken beginning just above the mouth of Willow Creek and going down the stream. This will present such changes as we found in their natural order.

SAMPLES TAKEN ABOVE MOUTH OF WILLOW CREEK

Analytical Results	Percent	Combined	Grains per Gal.
Carbon	1.685*	Carbon	0.090
Silicic acid	43.395	Calcic Sulfate	0.553
Sulfuric acid	6.096	Calcic Carbonate	1.497
Carbonic acid	13.352	Magnesic Chlorid	0.066
Phosphoric acid	0.229	Magnesic Carbonate	0.148
Chlorin	0.907	Magnesic Phosphate	0.019
Calcic oxid	19.845	Magnesic silicate	0.283
Magnesic oxid	3.791	Potassic Silicate	0.255
Potassic oxid	2.886	Sodic Silicate	0.542
Sodic oxid	6.759	Ferric oxid	0.035
Ferric oxid	0.610	Manganic oxid	0.032
Manganic oxid (br)	0.657	Excess Silicic acid	1.899
Sum	100.212	Total	5.420
Oxygen equivalent to Chlorin	0.212		
Total	100.000		

The total solids in this water was 5.39 grains per imperial gallon. Loss on ignition 1.2 grains.

*The carbon was separated during the drying necessary to render the residue anhydrous and is given as such in the analysis. Of course, it was present as organic matter which could not be burned out of such a mixture without altering its composition and yet this organic matter rendered the solution very difficult to work if not destroyed.

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Sanitary Analysis

	Parts per Million
Total solids	77.0000000
Chlorin	.0001400
Nitrogen as nitrates	None
Nitrogen as nitrites	.0000700
Saline ammonia	.0000014
Albuminoidal ammonia	.0000021

SAMPLE TAKEN AT DEL NORTE

Analytical Results	Percent
Carbon	3.032
Silicic acid	32.102
Sulfuric acid	7.870
Carbonic acid	14.710
Chlorin	1.514
Calcic oxid	19.350
Magnesic oxid	3.428
Potassic oxid	2.893
Sodic oxid	8.481
Ferric oxid	0.721
Aluminic oxid	0.399
Manganic oxid (br)	0.120
Ignition	(5.722)
Sum	100.342
Oxygen equivalent to Chlorin	342
Total	100.000

Combined	Grains per Imp. Gal.
Calcic Sulfate	0.7753
Calcic Carbonate	1.4301
Magnesic Carbonate	0.4105
Sodic Carbonate	0.0166
Sodic Chlorid	0.1447
Sodic Silicate	0.7798
Potassic Silicate	0.2749
Ferric oxid	0.0412
Aluminic oxid	0.0231
Manganic oxid	0.0069
Carbon	0.1716
Excess Silicic acid	1.3767
Total	5.4559

Total solids in the water 5.46 grains per imp. gal.; loss on ignition 1.26 grains. The loss on ignition probably includes a large part, if not all, of the carbonic acid, owing to the action of free silicic acid.

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SAMPLE TAKEN AT MONTE VISTA

Analytical results	Percent	Combined*	Grains per Imp. Gal.
Carbon	2.227		
Silicic acid	31.372	Calcic Sulfate	0.7954
Sulfuric acid	7.570	Calcic Carbonate	1.6953
Carbonic acid	16.120	Magnesic Carbonate	0.4498
Phosphoric acid	Trace	Sodic Carbonate	0.0366
Chlorin	1.541	Sodic Chlorid	0.1570
Calcic oxid	20.700	Sodic Silicate	0.8439
Magnesic oxid	3.484	Potassic silicate	0.2914
Potassic oxid	2.876	Ferric oxid	0.0355
Sodic oxid	8.782	Aluminic oxid	0.0155
Ferric oxid	0.574	Manganic oxid (br)	0.0054
Aluminic oxid	0.251	Carbon	0.1375
Manganic oxid (br)	0.088	Excess Silicic acid	1.4178
Ignition	(4.761)		
Sum	100.348	Total	5.8811
Oxygen equivalent to chlorin	0.348		
Total	100.000		

Total solids 5.88 grains per imperial gallon. Loss on ignition 1.68 grains. nil.

SAMPLES TAKEN AT ALAMOSA 30 SEPT., 1908

Analytical results	Percent	Combined	Grains per Imp. Gal.
Silicic acid	28.312		
Sulfuric acid	8.837	Calcic Sulfate	1.4277
Carbonic acid	16.386	Calcic Carbonate	2.1450
Chlorin	2.053	Magnesic Carbonate	0.7136
Calcic oxid	21.797	Potassic Carbonate	0.2871
Magnesic oxid	3.978	Potassic Chlorid	0.0635
Potassic oxid	2.747	Sodic Chlorid	0.2409
Sodic oxid	9.709	Sodic Silicate	1.3917
Ferric oxid	0.559	Ferric oxid	0.0480
Aluminic oxid	0.583	Aluminic oxid	0.0500
Manganic oxid (br)	0.098	Manganic oxid (br)	0.0084
Ignition	(5.404)	Excess Silicic acid	1.7441
Sum	100.463	Total	8.1000
Oxygen equivalent to Chlorin	0.463		
Total	100.000		

Total solids 8.12 grains per imperial gallon. Loss on ignition 1.68 grains.

SANITARY ANALYSIS

	Parts per Million
Total solids	101.71428
Loss on ignition	24.00000
Chlorin	2.00000
Nitrogen as nitrates	0.00030
Saline Ammonia	0.01200
Nitrogen as nitrites	0.03000

*In this and the preceding analysis the loss on ignition is not included in the statement of grains per gallon because all of the errors are thrown into this factor and its influence upon the statement of the analysis is practically

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SAMPLES TAKEN AT STEWART'S PLACE 6 OCT., 1908

Analytical results	Percent	Combined	Grains per Imp. Gal.
Silicic acid	23.392		
Sulfuric acid	10.222	Calcic Sulfate	1.5860
Carbonic acid	16.289	Calcic Carbonate	2.8244
Phosphoric acid	Trace	Magnesic Carbonate	0.3761
Calcic oxid	24.644	Potassic Carbonate	0.1337
Magnesic oxid	1.949	Potassic Chlorid	0.2227
Potassic oxid	2.553	Sodic Chlorid	0.1815
Sodic oxid	10.239	Sodic Silicate	1.6454
Ferric oxid	0.686	Ferric oxid	0.0620
Aluminic oxid	0.475	Aluminic oxid	0.0432
Manganic oxid (br)	0.111	Manganic oxid (br)	0.0101
Ignition	(7.569)	Excess Silicic acid	1.3145
Sum	100.536	Total	8.3996
Oxygen equivalent to Chlorin	0.536		
Total	100.000		

Total solids 8.4 grains per imperial gallon. Loss on ignition 2.24 grains.

SAMPLE TAKEN AT STATE BRIDGE 10 OCT., 1908

Analytical results	Percent	Combined	Grains per Imp. Gal.
Silicic acid	22.568		
Sulfuric acid	11.674	Calcic Sulfate	1.8700
Carbonic acid	17.193	Calcic Carbonate	2.3570
Phosphoric acid	Trace	Magnesic Carbonate	0.8747
Chlorin	2.228	Potassic Carbonate	0.3840
Calcic oxid	22.204	Sodic Carbonate	0.0114
Magnesic oxid	4.444	Sodic Chlorid	0.3463
Potassic oxid	2.780	Sodic Silicate	1.6093
Sodic oxid	10.685	Ferric oxid	0.0486
Ferric oxid	0.517	Aluminic oxid	0.0520
Aluminic oxid	0.552	Manganic oxid (br)	0.0048
Manganic oxid (br)	0.049	Excess Silicic acid	1.3320
Ignition	(5.603)	Total	8.8900
Sum	100.502		
Oxygen equivalent to Chlorin	0.502		
Total	100.000		

Total solids 8.89 grains per imperial gallon. Loss on ignition 2.38 grains.

SANITARY ANALYSIS

	Parts per Million
Total solids	127.000000
Chlorin	0.000315
Nitrogen as nitrates	None
Nitrogen as nitrites	None
Saline Ammonia	None
Albuminoidal Ammonia	0.0000014

The distance between the points where the first and last of these Rio Grande waters were taken is not far from 100 miles, probably more than 60 of these are within the valley proper. The total solids

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increased only from 5.4 to 8.9 grains per imperial gallon though farms and pastured meadows border a large portion of its course and the three towns of Del Norte, Monte Vista and Alamosa are located on its banks. In addition to these factors, which usually cause radical changes in the character of our river waters, the Rio Grande may receive waters from the Alamosa, La Jara, Conejos and other streams. I cannot state from what streams the river received water at the time the sample was taken at the State Bridge. There was some water flowing into the Rio Grande from the Conejos but how much I do not know, neither do I know whether this flow was continuous or only accidental.

ANALYSES SEEM TO INDICATE THAT NO RETURN WATER FLOWS INTO RIVER

The analyses of the six samples taken at different points in the river, the extreme points being about 100 miles apart, show no differences in the character of the total solids held in solution and no differences in the quantity of solids held in solution that might not be accounted for by evaporation. These results are wholly different from those obtained in our study of the Poudre, the Arkansas and other streams. These results are, however, in harmony with the inferences to be drawn from the topography of the valley, i. e., from the fact that the bed of the river is higher than the valley and further that the volume of the flow is decidedly less as we go down the river, at least, as far as the State Bridge. At this point the flow of the river during the months of August, September and October is usually very small, in fact, is never large, except during the months of flood, which are May and June, and, exceptionally, a part of July. The range of the flow for the other months of the year, given for the eight years of which I find records, is from 17 second feet in August, 1902, to 196 second feet in September, 1904. The usual flow is considerably under 75 second feet. The flow at Del Norte for the same months and years was 152 second feet in August, 1902, and 689 second feet in September, 1904.* The irrigating canals take out, at times, nearly all of the water by the time it passes a little way beyond Monte Vista.

If any volume of return waters finds its way into the river, it would follow from our results, that these waters have the same characteristics and composition as the river water before it is used for irrigating the land or while it is still within the mountain section of its course. This is very improbable, or, judging from our knowledge of the changes which take place in the waters of other streams, impossible.

*These data are taken from U. S. Geo. Survey Water Supply Paper No. 240. C. E. Siebenthal.

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The nature of the land irrigated with the water taken from the Rio Grande, as it abounds in alkali salts, practically precludes the possibility that return waters should have the composition of that applied as irrigating water. There are, it is true, two classes of water which might be considered as furnishing an increase in the flow of the river, i. e., waters previously used for irrigation, yielding what we usually understand as return waters, and artesian waters. The latter class of waters occur throughout the greater part of the cultivated portion of the valley. I am informed that, up to the present time, some 5,500 artesian wells have been sunk in the valley. The fact that some of these wells are not flowing at the surface does not necessarily preclude their discharge of water into the valley in such a way as to affect the water problems of the soil and the river. The great majority of these wells are, however, flowing freely and but few of them are cased for more than a few feet, leaving the waters entirely free to fill up any strata not already full and to affect in this way the general water problems of the valley.

While our problem clearly contains these factors, we assume that the waters, the river being for the most part actually higher than the neighboring portions of the valley, retain their character because there is actually no admixture of other waters. This assumes that the Rio Grande actually fails to drain the valley. I believe that this assumption is essentially correct and consider the results obtained in the analyses of the water as positively indicating this condition.

There are two classes of artesian waters, white and brown. If the former class should find their way into the river through strata of sand, or as springs, they would not affect the character of the river water. The flow of the river might be increased in this way and the character of the water not changed any more than we find indicated by our analyses, namely, a slight increase in the quantity of the solids held in solution without any essential change in their character. In making this statement I am not forgetful of the fact that the increase in the amount of solids contained in the water may be accounted for by evaporation. It must be remembered that the increase found is only 3.5 grains per imperial gallon in samples taken at points in the river 100 miles apart. While we shall neglect the effects of evaporation it is evident that it may be an important factor.

Prof. L. G. Carpenter gives, in a bulletin not yet issued, the results of river gaugings in August, 1898, which show a total gain between the U. S. Gauging Station above Del Norte and the State Bridge, of 15.75 ft.; in 1900, a total gain of 63.06 ft.; in 1901, a total loss of 11.01 ft.; in 1902, a total loss of 37.7 ft.; and in 1910, a total gain of 46.19 ft. Our samples of river water were taken in 1908 for

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which year we unfortunately have no gaugings so we do not know whether the flow would have shown a gain or loss between the U. S. Gauging Station and the State Bridge.

THE GROUND-WATER AND ALKALIS SOUTH AND WEST OF THE RIVER

The statement has been made that no return waters could be finding their way into the river, and the reason assigned was that, owing to the character of the soil and the prevalence of alkali, such waters would change the composition of the river water. We have, in fact, no return waters by whose composition we can definitely demonstrate that this is the case—the best that we can do is to present some ground- and drain-waters.

The use of these, unfortunately, needs an explanation as to why they are of limited and not of general application to the whole valley. Any samples taken to the south and west of the river would be applicable to this portion of the valley but samples taken north of the river and in the eastern part of the valley, about Hooper for instance, would not apply to that portion of the valley south and west of the river, though both sections abound in alkalis.

There are two classes of artesian wells in the valley which are commonly designated as white and brown waters. The former waters are colorless and of excellent quality, the latter are of various shades of brown. Analyses of these waters will be given subsequently, but it may be stated here that these brown waters differ in composition from the white waters in carrying considerable quantities of sodic carbonate which forms, in the deeper strata, a solution of humus, imparting the brown color to the waters. These brown waters are confined to the northern and eastern part of the valley. I may anticipate a little by stating that the color of the water is determined by the humus obtained from the strata underlying this section of the valley and in this case may be taken as definite proof of the presence of sodic carbonate, but the converse of this, that a colorless water is free from sodic carbonate, is not necessarily true.

Our statement is practically this, that no ground or return waters are finding their way into the Rio Grande during its flow through the valley, because the composition of its waters retains the characteristics which it possesses on entering the valley, those of a mountain water, i. e., such as contain carbonates as the essential salts in solution with subordinate quantities of sulfates and chlorids with an excess of silicic acid. The character of the ground and drainage waters will undoubtedly vary somewhat from place to place, but their general character will persist just as the character of mountain waters per-

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sists. In the ground waters the sulfates and chlorids become predominant, the carbonates of the alkaline earths and the silicates recede or disappear while the carbonate of soda is usually present in small quantities.

The following sample of ground-water was taken from SE.¼ sec. 23, T. 38 N., R. 8 E. and less than 400 feet from a drainage ditch which had been opened for 21 months at the time the sample was taken. The land had never been cultivated, cleared or in any way improved, The water was encountered at 3′ 11″ in stratum of sand. Beneath this was a clay mixed with large quantities of calcic sulfate and carbonate. I do not know whether the neighboring drainage ditch had lowered the level of the ground water or not. This water did not come from the irrigation of land in the immediate neighborhood. I consider it as representing the permanent ground water of this locality.

ANALYSIS OF GROUND-WATER
SE. ¼ sec. 23, T. 38 N., R. 8 E.

Analytical results	Percent	Combined	Percent
Silicic acid	6.303	Calcic sulfate	55.647
Sulfuric acid	32.720	Calcic carbonate	15.081
Carbonic acid	6.931	Magnesic carbonate	0.577
Chlorin	8.795	Magnesic chlorid	11.809
Calcic oxid	31.378	Magnesic silicate	3.233
Magnesic oxid	6.870	Potassic silicate	0.377
Potassic oxid	0.230	Sodic silicate	8.441
Sodic oxid	4.279	Ferric and Alum. oxids.	0.075
Ferric and Alum. oxids.	0.075	Excess Silicic acid	0.056
Ignition	(4.704)	Ignition	(4.704)
Sum	101.985	Total	100.000
Oxygen equivalent to Chlorin	1.985		
Total	100.000		

Total solids 98.9 grains per imperial gallon. Loss on ignition 16.9 grains.

The drainage ditch referred to in connection with the preceding ground-water was upwards of 4 miles long at this time and was being extended. The discharge was given to me as varying from 4 to 10 second feet. At this time it was carrying the smaller amount, about 4 second feet. There was probably no admixture of run-off water in the ditch at this time, so we may take the results obtained in the analyses of this drain-water as representing the ground-water in the land above the point at which the sample was taken, probably a mile and a half below the then upper end of the ditch.

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ANALYSIS OF DRAINAGE-WATER
Parma Land Company Ditch

Analytical results	Percent	Combined	
Carbon	3.102	Carbon	3.102
Silicic acid	8.105	Calcic sulfate	49.087
Sulfuric acid	28.863	Calcic carbonate	5.835
Carbonic acid	8.536	Magnesic carbonate	6.655
Chlorin	9.561	Potassic carbonate	0.106
Calcic oxid	23.495	Sodic carbonate	5.946
Magnesic oxid	3.184	Sodic chlorid	15.778
Potassic oxid	0.072	Sodic silicate	5.338
Sodic oxid	14.560	Ferric and Alum. oxids.	0.089
Ferric and Alum. oxids.	0.098	Excess silicic acid	5.473
Manganic oxid	0.089	Ignition	(2.493)
Ignition	(2.493)	Total	100.000
Sum	102.158		
Oxygen equivalent to Chlorin	2.158		
Total	100.000		

The remoteness of the relation between the alkalis or in the surface portions of the land and the salts removed by the drainage-waters is made evident by the analyses of the alkalis from the land through which this drain, or its laterals, run.

This sample of alkali was taken a few feet from a lateral open drain emptying into the main ditch a few hundred feet south of this point.

ANALYSIS OF ALKALI
Sample taken just inside Parma Land Company's Gate

	Percent
Silicic acid	0.065
Calcic sulfate	8.135
Magnesic sulfate	6.209
Sodic sulfate	61.473
Sodic chlorid	20.974
Organic matter	3.144
Sum	100.000

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ALKALI NE.¼ SEC 14, T. 38 N., R. 8 E. PARMA LAND CO.

Analytical Results	Percent	Combined	Percent
Silicic acid	0.345	Calcic sulfate	10.347
Sulfuric acid	45.463	Magnesic sulfate	2.121
Carbonic acid	Trace	Potassic sulfate	10.314
Chlorin	8.352	Sodic sulfate	59.010
Calcic oxid	4.263	Sodic chlorid	13.782
Magnesic oxid	0.710	Sodic silicate	0.681
Potassic oxid	5.578	Excess Sodic oxid	0.586
Sodic oxid	34.015	Ignition	(3.159)
Ignition	(3.159)		
Sum	101.885	Total	100.000
Oxygen equivalent to Chlorin	1.885		
Total	100.000		

The crust on the soil was very thin. The soluble portion of the sample as taken was 5.88 percent.

The next sample was taken from the same section as the preceding but at a subsequent time. The sample was prepared by the manager, Mr. W. H. Sommers.

ALKALI—SAME LOCALITY AS PRECEDING

Analytical results	Percent	Combined	Percent
Silicic acid	1.232	Calcic sulfate	4.040
Sulfuric acid	43.665	Magnesic sulfate	2.242
Chlorin	9.667	Potassic sulfate	8.015
Calcic oxid	1.667	Sodic sulfate	64.143
Magnesic oxid	0.751	Sodic chlorid	15.593
Potassic oxid	4.336	Sodic silicate	2.481
Sodic oxid	33.563	Ferric and Alum. oxids.	0.176
Ferric and Alum. oxids.	0.176	Excess sodic oxid	1.875
Ignition	(1.125)	Ignition	(1.125)
Sum	102.182	Total	100.000
Oxygen equivalent to Chlorin	2.182		
Total	100.000		

The next alkali was collected from the bank of the drainage-ditch of the Parma Land Company. Incrustation as taken varied from 1 inch to 2 inches in thickness. The water-soluble portion of the sample equalled 27.7 percent.

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ALKALI—DRAINAGE DITCH, PARMA

Analytical results	Percent	Combined	Percent
Silicic acid	0.922	Calcic sulfate	1.456
Sulfuric acid	52.779	Magnesic sulfate	0.326
Carbonic acid	0.540	Potassic sulfate	1.442
Chlorin	0.815	Sodic sulfate	90.639
Calcic oxid	0.600	Sodic carbonate	1.302
Magnesic oxid	0.109	Sodic chlorid	1.345
Potassic oxid	0.780	Sodic silicate	0.869
Sodic oxid	41.532	Ferric and Alum. oxids.	0.160
Ferric and Alum. oxids.	0.160	Manganic oxid	0.030
Manganic oxid	0.030	Excess Silicic acid	0.504
Ignition	(1.927)	Ignition	(1.927)
Sum	100.184	Total	100.000
Oxygen equivalent to Chlorin	.184		
Total	100.000		

ALKALI

(This sample was taken because we took a sample of ground-water at the same place, SE. ¼ sec. 23 T. 38 N, R. 8 E. The incrustation as gathered yielded 7.4 prcent of its weight to water.)

Analytical results	Percent	Combined	Percent
Silicic acid	1.044	Calcic sulfate	0.874
Sulfuric acid	46.816	Magnesic sulfate	0.033
Carbonic acid	1.440	Potassic sulfate	3.217
Chlorin	4.468	Sodic sulfate	79.557
Calcic oxid	0.360	Sodic carbonate	3.472
Magnesic oxid	0.011	Sodic chlorid	7.373
Potassic oxid	1.740	Sodic silicate	0.748
Sodic oxid	41.087	Ferric and Alum. oxids.	0.130
Ferric and Alum. oxids.	0.130	Excess Silicic acid	0.684
Ignition	(3.912)	Ignition	(3.912)
Sum	101.008	Total	100.000
Oxygen equivalent to Chlorin	1.008		
Total	100.000		

A sample of the soil and subsoil was also taken at this place. The series of analyses thus presents as complete a set of analytical data as we can present from the chemical standpoint.

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ANALYSES OF THE SOIL SAMPLES DRIED AT 100° C.

	Soil 7 inches deep	Subsoil Sample 10 inches
	Percent	Percent
Insoluble (sand)	56.271	51.285
Soluble silicic acid	17.531	11.662
Sulfuric acid	0.255	0.128
Phosphoric acid	0.651	0.019
Carbonic acid	3.956	10.207
Chlorin	0.462	0.184
Calcic oxid	6.900	14.318
Magnesic oxid	1.618	1.444
Potassic oxid	1.047	1.183
Sodic oxid	1.464	0.679
Ferric oxid	4.420	3.567
Aluminic oxid	3.382	2.868
Manganic oxid	0.192	0.161
Ignition	1.867	3.085
Sum	100.017	100.790
Oxygen equivalent to chlorin	0.104	0.042
Total	99.913	100.748
Total Nitrogen	0.071	0.050

These analyses show that the soda salts were very largely in the top 7 inches of soil and that the calcium carbonate probably was concentrated below the surface soil which was, at this place, 7 inches deep. Our marls sometimes contain calcium as a silicate. This may, by giving rise to soluble double silicates, account for the high silicic acid in some of the alkalis.

The preceding samples of alkali were all taken in the latter part of the summer, mostly in the month of August. This is a season when the general prevalence of alkali is not apparent as in mid or late spring, especially after light snows or rains. At this time we sometimes find areas of several square miles in a body white with these alkalis.

The following sample was taken on 8 May, 1916, in the same general section of country in which the preceding samples were taken. This land has never been cultivated, so I doubt whether it has ever been irrigated. The principal vegetation is chico and greasewood (*Sarcobatus and Bigelovia*). The surface of the ground at this time was perfectly white over an area of many, probably 15 or 20 square miles.

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ALKALI FROM UNCULTIVATED LAND

Sample taken from near Parma. The portion soluble in water equalled 27.55 percent

Analytical results	Percent	Combined	Percent
Carbon	0.070	Carbon	0.070
Silicic acid	0.165	Calcic sulfate	3.474
Sulfuric acid	54.222	Magnesic sulfate	0.462
Carbonic acid	0.358	Potassic sulfate	0.652
Phosphoric acid	0.152	Sodic sulfate	91.507
Chlorin	0.632	Sodic carbonate	0.863
Calcic oxid	1.431	Sodic phosphate	0.352
Magnesic oxid	0.155	Sodic chlorid	1.043
Potassic oxid	0.352	Sodic silicate	0.334
Sodic oxid	41.506	Ferric and Alum. oxids.	0.001
Ferric and Alum. oxids.	0.001	Manganic oxid (br)	0.338
Manganic oxid	0.338	Excess sodic oxid	0.143
Ignition	(0.761)	Ignition	(0.761)
Sum	100.143	Total	100.000
Oxygen equivalent to chlorin	.143		
Total	100.000		

It is not safe to assume that the alkali covering this large area was identical in the details of its composition, but it is safe to assume that this analysis represents the general character of all of the alkali in this area, and even further, that this is the general type of alkali occurring in this whole section of the valley. We have other analyses that support this statement, but I consider it needless to indicate how general this type of alkali is. I took a sample of alkali within the limits of the town of Alamosa which on analysis proved to consist of upwards of 96.0 percent of sodic sulfate. This alkali occurred very abundantly at the point where it was collected and the following note entered at the time the sample was collected may be of some interest:

"The lot adjoining the one from which this sample was collected. was improved and the house occupied. The lawn (blue grass) was excellent, and the garden in fine condition. Corn, beets, peas, cabbage, carrots and potatoes were growing thriftily."

Another sample of alkali collected near La Jara some 16 miles south of the Alamosa sample, contained 25.5 percent of water-soluble of which 91.0 percent was sodic sulfate. Two samples of soil were taken with this last sample. One of them represented the top 2 inches of soil of a cultivated field; the other one represented the succeeding 4 inches. The following partial statement will suffice for our purpose:

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WATER-SOLUBLE IN TWO SAMPLES OF SOIL FROM LA JARA

Top 2 inches	Percent	Succeeding 4 inches	Percent
Water-soluble	3.05	Water-soluble	1.50
Calcic sulfate	12.76	Calcic sulfate	30.17
Magnesic sulfate	2.30	Magnesic sulfate	4.44
Sodic sulfate	65.21	Sodic sulfate	46.12
Potassic sulfate	0.736	Potassic sulfate	7.29

This land was occupied by a crop of peas at the time the samples were taken. The stand was irregular but the peas were, in the main, fairly thrifty.

NO RETURN WATERS FROM SOUTH AND WEST

I have presented the composition of the drainage, the ground-waters, the alkalis and the soil extracts of a section of the valley lying south and west of the Rio Grande to a sufficient extent and in sufficient detail to support the statement made, that return waters from this section cannot, in any considerable quantity, find their way into the Rio Grande. The flow of the river is so small (as low as 17 second-feet at times), while the maximum found at the State Bridge in 7 years' observation, was only 150 second-feet for the month of August, that the ground-water would change wholly the character of the river-water, which is contrary to what we found in 1908. Further, the gaugings carried out under the direction of Prof. Carpenter, show a loss about as often as they show a gain.

This last observation would seem just as applicable to the area north and east of the river as to that south and west of it. The conditions north and east of the river are not the same as those obtaining south and west of it. If the surface conditions ever were the same, which I am inclined to think was the case, at least in the main, in the early nineties, say 1894, they are no longer so.

The character and importance of the results that have followed justify a more complete presentation of the facts than I shall be able to give. Nevertheless, we can present the big features of these facts just as we have done for the section already discussed.

CONDITIONS NORTH AND EAST OF THE RIVER

I will digress to justify in a measure the acknowledgement of insufficiency contained in the last sentences which, however, will come to light again and again in the following pages. In the first place, the area of the valley mentioned here does not lie wholly within Colorado, and is credited with a total area of 900 square miles. The area which is discussed probably exceeds 3,300 square miles within which we encounter unusual conditions; for instance, practically the whole of this

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area constitutes an artesian basin, but this artesian water varies greatly in its character. We have already presented the fact that we have immense quantities of soluble salts in our soil which, so far as we have presented them, are almost harmless but they constitute a factor which cannot be disregarded; in fact, many evils are attributed to these same salts by the public at large and by some students of our agricultural conditions. The character of these soluble salts may change from place to place in so large a territory without our chancing to discover it and statements which are perfectly applicable to one place might be a sad misfit applied to another. But, with all this, the main features of our presentation are without doubt faithful to the facts. We shall give, as we proceed, facts which we believe justify our views. Some of these facts, both of conditions and practices, may be unusual in other places and still be very real in this area.

We shall now proceed to present the facts pertaining to the ground-waters, soil extracts and alkalis of that section of the valley designated as the Hooper Mosca section. The limits of this section are difficult to define. This does not matter much on the eastern side but the limits to the west are important. This will be appreciated when it is stated that to the eastward of the D. & R. G. Railroad, we soon encounter land that is still open to entry under the desert-land laws, while to the westward lies land that 30 years ago was under cultivation and produced excellent crops—from 30 to 50 bushels of wheat to the acre—but this is not now true of much of the land lying within 14 to 16 miles west of it. This is a part of the reason why I stated that I believe that conditions have changed since the period of this productiveness. The reason seems sufficient and the conclusion self-evident.

The first ground- and drain-waters are from the extreme western portion of this district.

GROUND-WATER SW. ¼ SEC. 24, T. 40 N., R. 8 E.

Analytical results	Percent	Combined	Percent
Carbon	1.128	Carbon	1.128
Silicic acid	5.356	Calcic sulfate	29.453
Sulfuric acid	26.081	Magnesic sulfate	10.750
Phosphoric acid	0.169	Sodic sulfate	2.863
Carbonic acid	6.185	Sodic phosphate	0.506
Chlorin	16.311	Sodic carbonate	14.914
Calcic oxid	12.135	Potassic chlorid	6.162
Magnesic oxid	3.599	Sodic chlorid	22.081
Potassic oxid	3.893	Sodic silicate	7.232
Sodic oxid	25.703	Ferric and Alum. oxids	0.463
Ferric and Alum oxids.	0.463	Manganic oxid	0.089
Manganic oxid (br)	0.089	Excessive Silicic acid	1.790
Ignition	(2.569)	Ignition	(2.569)
Sum	103.681	Total	100.000
Oxygen equivalent to chlorin	3.681		
Total	100.000		

Total solids 56.56 grains per imperial gallon. Loss on ignition 7.07 grains.

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DRAIN-WATER SW. ¼ SEC. 24, T. 40 N., R 8 E.

Analytical Results	Percent	Combined	Percent
Carbon	1.563	Carbon	1.563
Silicic acid	14.456	Calcic sulfate	24.995
Sulfuric acid	14.697	Calcic phosphate	0.310
Phosphoric acid	0.142	Calcic carbonate	12.406
Carbonic acid	14.813	Magnesic carbonate	10.934
Chlorin	6.309	Potassic carbonate	9.213
Calcic oxid	17.418	Sodic carbonate	1.748
Magnesic oxid	5.231	Sodic chlorid	10.411
Potassic oxid	6.282	Sodic silicate	19.726
Sodic oxid	16.549	Ferric and Alum. oxids.	0.205
Ferric and Alum. oxids.	0.205	Manganic oxid	0.210
Manganic oxid (br)	0.210	Excess Silicic acid	4.730
Ignition	(3.549)	Ignition	(3.549)
Sum	101.424	Total	100.000
Oxygen equivalent to chlorin	1.424		
Total	100.000		

Total solids 21.8 grains per imperial gallon.
Loss on ignition 8.6 grains.

The above analyses are given to show the general composition of the ground- and drain-waters in this portion of the district under discussion and to show that they are widely different from the Rio Grande water proper, but they also serve very well to show the differences between a ground-water and a drain-water for they were taken within a very short distance of one another.

The next samples of water are from the center of this district. The lake-water was from a temporary lake and probably represents run-off water.

GROUND-WATER MOSCA

	Percent
Silicic acid	2.226
Sulfuric acid	37.249
Phosphoric acid	0.076
Chlorin	5.342
Carbonic acid	10.042
Calcic oxid	4.651
Magnesic oxid	2.906
Potassic oxid	3.596
Sodic oxid	34.289
Ferric and Alum. oxids.	0.035
Manganic oxid (br)	0.059
Ignition	(3.792)
Sum	102.263
Oxygen equivalent to chlorin	2.263
Total	100.000

TEMPORARY LAKE, RUN-OFF WATER
Partial Analysis

	Percent
Sodic sulfate	69.92
Sodic carbonate	13.91
Sodic chlorid	14.54
Ferric and Alum oxids.	0.56
Calcic oxid	0.61
Silicic acid	0.85
	100.39

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The next sample is a ground-water from a drained, cultivated field. The draining was effected at this place by an open ditch and as the water plane had fallen below the bottom of the ditch there was no other than ground-water to be obtained. This residue was also prepared in the field and the total solids are not given.

GROUND-WATER. DIBBERS, MOSCA

Analytical Results	Percent	Combined	Percent
Silicic acid	9.591	Calcic sulfate	25.312
Sulfuric acid	22.588	Magnesic sulfate	11.589
Carbonic acid	11.790	Magnesic carbonate	1.332
Chlorin	5.018	Potassic carbonate	11.857
Calcic oxid	10.429	Sodic carbonate	17.661
Magnesic oxid	4.512	Sodic chlorid	8.281
Potassic oxid	8.085	Sodic silicate	16.240
Sodic oxid	22.965	Ferric and Alum. oxids.	0.542
Ferric and Alum. oxids.	0.542	Manganic oxid (br)	0.054
Manganic oxid (br)	0.054	Excess silicic acid	1.584
Ignition	(5.548)	Ignition	(5.548)
Sum	101.131	Total	100.000
Oxygen equivalent to chlorin	1.131		
Total	100.000		

ALKALIS

(These two samples of effloresced alkalis were collected 4 miles south and 5 miles west of Hooper.)

NW. ¼ sec. 23, T. 40 N., R. 9 E.	Percent	SE. ¼ sec. 15, T. 40 N., R 9 E.	Percent
Silicic acid	0.200	Silicic acid	0.427
Sulfuric acid	51.436	Sulfuric acid	52.175
Chlorin	3.463	Carbonic acid	0.992
Nitric acid	Present	Chlorin	2.712
Calcic oxid	3.300	Calcic oxid	0.223
Magnesic oxid	0.522	Magnesic oxid	Trace
Potassic oxid	2.831	Potassic oxid	1.164
Sodic oxid	35.800	Sodic oxid	41.282
Ignition	3.228	Ferric and Alum. oxids.	0.135
		Ignition	(1.530)
Sum	100.780	Sum	100.620
Oxygen equivalent to chlorin	.780	Oxygen quivalent to chlorin	.620
Total	100.000	Total	100.000

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ALKALI

From Uncultivated Land at Hooper, Greasewood (Sarcobatus) Abundant

Analytical Results	Percent	Combined	Percent
Silicic acid	0.355	Calcic sulfate	4.155
Sulfuric acid	46.810	Magnesic sulfate	0.459
Carbonic acid	3.451	Potassic sulfate	3.143
Chlorin	1.589	Sodic sulfate	75.688
Calcic oxid	1.712	Sodic carbonate	8.321
Magnesic oxid	0.153	Sodic chlorid	2.621
Potassic oxid	1.699	Sodic silicate	0.721
Sodic oxid	40.202	Ferric and Alum. oxids.	0.081
Ferric and Alum. oxids.	0.081	Manganic oxid	0.090
Manganic oxid (br)	0.090	Excess sodic oxid	0.505
Ignition	(4.216)	Ignition	(4.216)
Sum	100.358	Total	100.000
Oxygen equivalent to chlorin	0.358		
Total	100.000		

THE WATER-SOLUBLE PORTION OF SOIL

From the same locality from which the preceding alkali was taken. It equalled 1.935 percent of air-dried soil.

Analytical Results	Percent	Combined*	Percent
Silicic acid	3.483	Calcic sulfate	1.456
Sulfuric acid	25.744	Magnesic sulfate	0.345
Phosphoric acid	0.211	Potassic sulfate	8.256
Carbonic acid	10.533	Sodic sulfate	37.085
Chlorin	9.702	Calcic phosphate	0.461
Calcic oxid	0.850	Sodic carbonate	25.398
Magnesic oxid	0.115	Sodic chlorid	16.010
Potassic oxid	4.483	Sodic silicate	7.617
Sodic oxid	40.893	Ferric and Alum. oxids.	0.030
Ferric and Alum. oxids.	0.030	Manganic oxid (br)	0.050
Manganic oxid (br)	0.050	Excess silicic acid	2.149
Ignition	5.503	Ignition	5.503
Sum	101.552	Total	99.360
Oxygen equivalent to chlorin	2.186		
Total	99.366		

*The amount of water-soluble carbonates in this soil extract is noteworthy.

The soil dried at 100° C. was digested with hydrochloric acid for 5 days and the solution gave the following results:

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SOIL, HOOPER, COLORADO. SAMPLE DRIED AT 100° C.

	Percent
Insoluble (sand)	62.241
Soluble silicic acid	15.229
Sulfuric acid	0.362
Phosphoric acid	0.320
Carbonic acid	2.629
Chlorin	0.081
Calcic oxid	4.295
Magnesic oxid	1.595
Potassic oxid	1.383
Sodic oxid	1.326
Ferric oxid	3.930
Aluminic oxid	4.259
Manganic oxid (br)	0.175
Ignition	2.260
Sum	100.085
Oxygen equivalent to chlorin	0.018
Total	100.067

These samples were collected in 1907. It is unfortunate that we cannot give the total solids present in these ground- and drain-waters but it can be stated that those from Sec. 24, T. 40, N., R. 8 E. were not remarkably rich, while those from the neighborhood of Mosca were quite rich. The drain-water from Sec. 24, T. 40 N., R. 8 E., however, is sufficiently rich in calcic sulfate to distinguish it from mountain waters though its other salts are very similar to the salts present in these. This is also a noticeable feature in the composition of the ground- and drain-waters previously given. The waters, alkalis, and soil extracts, so far given, with only one exception, are poor in chlorids. In this exception, the ground-water from Sec. 24. T. 40 N., R. 8 E., the chlorin, calculated as sodic chlorid, amounts to 22.0 percent of the total solids, which were not excessively abundant.

WATERS ON EITHER SIDE OF RIVER DIFFER GREATLY FROM RIVER-WATER

These data present the conditions existing on both sides of the Rio Grande up to 1908 and they reveal no such marked differences as one acquainted with the sections might expect. They are, however, consistent in one point, namely, they show that the waters, whether they are surface-, ground- or drain-waters, differ from the Rio Grande waters in that they carry very greatly increased quantities of sulfates. The ground- and drain-waters of these sections differ from other ground- and drain-waters that we have studied in that they, in general, seem to carry the carbonates of the alkaline earths and an excess of silicic acid. This last feature is not for the moment the specific object of our study. The main point, in this part of our discussion, is that the character of the alkalis, the soil extracts, the ground- and

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drain-waters is such that an admixture of them with Rio Grande waters would reveal itself in the changed composition of the latter. We shall have further use for these data, but, for the present, the main purpose is to demonstrate the absence of their influence on the composition of the river water.

RELATION OF GREASEWOOD TO SODIC CARBONATE CONTENT OF SOIL

We may observe in passing that the last alkali given was collected amid greasewood (*Sarcobatus*)* bushes with the expectation of finding large quantities of sodic carbonate present, but we find only 8.3 percent of this salt in the water-soluble portion of the effloresced mass which, as gathered, probably contained 75.0 percent of its weight of surface soil. The aqueous extract of this soil, amounting to 1.94 percent of the soil, contained 25.4 percent of this salt, or 0.49 percent calculated on the soil. We have presented no sample of ground-water from this locality, for we took none.

The theory that soil about these bushes is rich in carbonates because of the nature of these plants was advanced by Prof. Hilgard. These greasewood (*Sarcobatus*) bushes may have been the cause of the presence of this carbonate in the soil but there is also another, and perhaps a better, explanation possible in this case, but we shall refer to this subsequently. In the following case the debris of the greasewood growth may have been the source of the carbonate, I know of no other probable source of the salt. The sample is of a virgin soil taken from a rather low place, with an abundant growth of greasewood (*Sarcobatus*). The surface soil yielded 3.71 percent of soluble salts to water. Organic matter was very abundant; there was no calcium, and only a trace of magnesium present. The acid determined and calculated as sodic salts corresponds to sodic sulfate 44.8 percent, sodic carbonate 31.7 percent, sodic chlorid 8.0 percent and organic matter 15.0 percent. This sample of soil was not taken to a greater depth than 2 inches. The sodic carbonate in this sample amounts to 1.1 percent of the soil and its presence may account for the growth of the *Sarcobatus*. It is a question whether any other plant can tolerate so large an amount of this salt, owing to its toxic qualities. Another sample of alkali containing sodic carbonate was obtained two miles from the latter. It would not be at all unreasonable to attribute the occurrence of the sodic carbonate in the two preceding samples to the prevalence of the greasewood, but in this case, I know of no source to which it could reasonably be attributed, therefore, I have considered it as an isolated sample of little or no importance, an exception, a curiosity among our alkali waters. The dried salt consisted of:

*Bigelovia is locally called "Greasewood" and this is the reason for the word, "Sarcobatus" in parentheses.

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Sodic sulfate	31.780
Calcic sulfate	0.928
Sodic chlorid	6.691
Sodic carbonate	39.706
Organic matter	20.896
	100.000

The last two samples were met with in the section south and west of the Rio Grande. The explanations offered are the only ones possible in this case. These are, so far as I know, of very limited occurrence, and could not in any event modify in any important manner the character of the Rio Grande waters though they might be local factors in the unproductiveness of the soil.

THE PRODUCTION OF SODIC CARBONATE FROM THE FELSPARS

While there are differences between the composition of the Rio Grande water and the drain- and ground-waters, and the extracts of the soils presented, there are also persistent resemblances which we did not find in our stuly of these subjects in the neighborhood of Fort Collins and other sections.

In an article entitled "The Significance of Silicic Acid in the Mountain Waters, etc.,"* I pointed out that the characteristic results of the action of natural waters on the felspars is the production of a solution carrying principally the carbonates of the alkaline earths and alkalis with some sulfates and chlorids. Of the carbonates of the alkalis, the carbonate of soda occurs in excessively large amounts in proportion to the amount of soda in the felspar; in other words, the amounts of lime and soda taken into solution indicate the predominant decomposition of the soda-lime felspars. This characteristic in the composition of the salts in solution persists almost wholly unmodified in the Rio Grande water in spite of the long distance that it flows through the valley, but it also persists in the drain and ground waters in a marked degree with only one pronounced modification, namely, the increase of sulfates; the ground-water, for instance, from SE. ¼, sec. 23, T. 38 N., R. 8 E., or the drain-water from the Parma Land Company's ditch, or that taken from a drain in SE. ¼, sec. 24, T. 40 N., R. 8 E., might be taken for mountain waters, except for the large amounts of calcic sulfate present, which reach a maximum of 55.6 percent. It is not easily explicable why sodic carbonate does not appear in this analysis unless it be due to the abundance of calcic and magnesic oxids, but the appearance of this salt in ground- and drain-waters, as well as in river waters, is to be expected, except under such conditions as are indicated in the case just given.

Attention is called to these facts in this place, not only because these ground- and drain-waters present these characters, but also for

*Am. Jour. of Sc., Vol. XVI. Aug., 1903, pp. 169-184.

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the reason that the artesian waters, to be presented in this connection, will offer another phase of this, if not an entirely new question. It is for this reason that I call attention to the production of sodic carbonate in the decomposition of the felspars and at the same time to show that it is also possible to lay too much stress on this fact, as the sodic carbonate may be changed wholly into other forms. Still, it is a fact that sodic carbonate is almost always present in soil extracts and natural waters in larger or smaller quantities. The original source and general distribution of sodic carbonate may be easily explained, but these are not the questions to be answered in the case in hand, and do not answer the specific question presenting itself.

It is evident that neither the ground-waters nor solutions of these alkalis or soil extracts from either side of the river find their way into it, for if they did, they would both increase the amount of salts in the river-water and change their character.

THE ARTESIAN WATERS

Artesian water in the San Luis Valley was discovered by accident in 1887 and I am informed that there have been sunk, up to the present time, more than 5,500 such wells, ranging in depth from about 70 to upwards of 1,800 feet. It is indifferent, in our inquiry, whether any of these wells are used for irrigating purposes or not. Very many of these wells are now flowing at the surface, and but few of them are cased to any considerable depth and may consequently be furnishing water to the general supply of the valley by leakage, though they may not be flowing at the surface. We are, therefore, interested in the character of these waters.

There is a thoroughly justified classification of these artesian waters into white and brown, according to their color. The color, however, is probably due to an accident, the occurrence of humified matter in the strata of certain portions of the valley. It is possible that some of the white waters may contain the same mineral constituents as the brown water and that in as large quantities. This is more than a possibility, for every sample taken shows that the former statement, i. e., that the dissolved salts are the same in kind, is true, but the brown waters are usually richer in total solids. Two wells, locally designated as the gas-well and the soda-well, yielded waters which were not highly colored, but were comparatively rich in total solids. The water from the gas-well carried 37.63 grains, and that from the soda-well 103 grains of total solids per imperial gallon. In the brown water the upper flows are not strongly colored and are not excessively rich in total solids whereas the deeper flows are darker colored and are richer in total solids. The deepest flows, however, do not necessarily furnish the darkest waters.

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ANALYSES OF WHITE ARTESIAN WATERS

BUCHER WELL, ALAMOSA. DEPTH FROM WHICH FLOW COMES, 923 FEET. WATER IS COLORLESS

Analytical Results	Percent	Combined	Percent
Silicic acid	50.202	Calcic sulfate	5.689
Sulfuric acid	3.345	Calcic carbonate	0.951
Phosphoric acid	None	Potassic carbonate	2.791
Carbonic acid	14.346	Sodic carbonate	31.443
Chlorin	0.485	Sodic chlorid	0.800
Calcic oxid	2.877	Sodic silicate	8.756
Magnesic oxid	None	Ferric and Alum. oxids.	0.260
Potassic oxid	1.903	Excess Silicic acid	45.885
Sodic oxid	23.267	Ignition	3.081
Ferric and Alum. oxids.	0.260		
Manganic oxid	None	Total	99.656
Ignition	3.081		
Sum	99.766		
Oxygen equivalent to chlorin	0.110		
Total	99.656		

Total solids, 14.07 grains per imperial gallon. Loss on ignition, 2.2 grains. An older determination of the total solids in this water gave 15.9 grains.

Sanitary Analyses

	Parts per Million
Total solids	201.00000
Ignition	31.42860
Chlorin	3.00000
Nitrogen as Nitrates	0.00002
Nitrogen as Nitrites	0.01000
Saline Ammonia	0.00100
Albuminoidal ammonia	0.00400

WELL AT ELECTRIC LIGHT PLANT, ALAMOSA. DEPTH, 820 FEET. WATER IS COLORLESS

Analytical Results	Percent	Combined	Percent
Silicic acid	50.592	Calcic sulfate	4.976
Sulfuric acid	2.926	Calcic carbonate	2.104
Phosphoric acid	None	Potassic carbonate	2.898
Carbonic acid	14.610	Sodic carbonate	30.775
Chlorin	0.468	Sodic chlorid	0.772
Calcic oxid	3.229	Sodic silicate	11.175
Magnesic oxid	None	Ferric and Alum. oxids.	0.236
Potassic oxid	1.976	Manganic oxid	0.100
Sodic oxid	24.087	Excess of Silicic acid	45.082
Ferric and Alum. oxids.	0.236	Ignition	(1.882)
Manganic oxid	0.100		
Ignition	(1.882)	Total	100.000
Sum	100.106		
Oxygen equivalent to chlorin	0.106		
Total	100.000		

Total solids 14.63 grains per imperial gallon. Loss on ignition 2.59.

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Sanitary Analyses

	Parts per Million
Total solids	209.00000
Loss on ignition	37.00000
Nitrogen as nitrates	0.00270
Nitrogen as nitrites	0.07000
Chlorin	2.97060

The waters of the two wells just given represent the composition of the white artesian waters of this basin. I have an older analysis of the water from the Bucher well, we have also analyzed the water of the Spriesterbach and McNeiland wells, but the statement of these analyses in full would show only minor variations in analytical results and nothing more. The big features of the analyses are absolutely identical with the two already given. These wells are all comparatively deep ones. While there are very many shallow wells in the valley, from 70 to 250 feet deep, I have only one representative of these which is entered in my notes as "Widow Smith's place, depth of well uncertain, less than 300 feet, temperature 53° F., flow very strong". The only new point of interest in the analytical data of this well is the small amount of total solids that it contained, 6.6 grains per imperial gallon; otherwise we have essentially the same facts in regard to composition—very high silicic acid, abundance of sodic carbonate and some calcic sulfate. This sulfate is more abundant than usual, due, possibly, to the fact that the well was probably not cased for more than a few feet.

Some of these samples, together with others made by different analysts, may be found on p. 112 of Water Supply Paper No. 240, by Dr. C. E. Siebenthal of the U. S. Geological Survey.

Spring-Waters

In connection with white artesian waters, at least some of the spring waters deserve presentation. I regret, however, that I have studied these only in an incidental way. Some of these springs occur in the eastern part of the valley, under conditions which suggest that they may be directly connected with the artesian waters of the basin rather than with the surface waters as is usually the case. Some of these springs have a very considerable flow and are constant without any easily discernible source of supply. Other springs are not of this nature and evidently owe their supply to melting snows or surface waters; such springs should scarcely be considered in this connection.

Washington Springs may be taken as a type of some springs occurring in the eastern part of the valley. The artesian well mentioned as Widow Smith's was not far from these springs. There is one and may be more artesian wells at or near the springs at this time but these have been put down more recently and I know nothing about the composition of the water discharged by these. My impression is that the

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Widow Smith well closed up some years ago. The analyses of one of these spring-waters (there were five of them at the time the sample was taken) and of the water from the Widow Smith well, were made at the same time, some years ago. These two waters are identical in character and very similar in the details of composition. The spring-waters carry 5.8 grains total solids per gallon, the well-water 6.6; the spring-water 1.74 grains silicic acid, the well-water 1.89; the spring 2.98 grains carbonates, the well 1.64; the spring .98 grains of sulfates, the well 1.02 grains. These waters are so similar that the suggestion that they are both really artesian waters is reasonable. Against this may be offered the fact that the ground- and drain-waters so far given have not lost all of the characteristics of mountain-waters; for instance, they show the presence of carbonates and some silicic acid which may be at least partly free, for there are more acids than is sufficient to satisfy the bases present. Such a statement is correct, but does not consider the decided increase in the sulfates, nor does it consider the fact that the artesian waters differ from the mountain-waters in containing very subordinate quantities of the alkaline earths and always notably high percentages of sodic carbonate. The springs in the southern part of the valley, with which I am acquainted, are either within or at the edge of igneous rocks which form the San Luis Hills. This sheet of rocks might simply serve to divert the artesian waters upward, or the waters may come from beneath, finding their way through fissures. I have examined the Dexter and the McIntyre springs. These waters differ from the artesian waters that I have examined in that they are richer in lime than the artesian waters; this is especially true of the McIntyre springs, also, in that they are richer in sulfates, which is equally true of the two springs. In regard to the silicic acid, they retain the richness of artesian waters.

In this connection it may be asked why I have made no mention of bicarbonates but have expressed the facts as though there were no bicarbonates. We have worked almost entirely with water residues obtained by evaporation to dryness in which we would have only carbonates. These residues in many instances were prepared in the locality where the waters occurred, as this was the only practical plan of procedure. The samples that we sent to the laboratory were several days old before they were examined so we have not deemed the omission of the half bound or even free carbonic acid of much importance, especially as the primary object had in view concerned itself very largely with the question of the mineral constituents present in the water.

WHITE ARTESIAN AND SPRING WATERS WOULD NOT AFFECT RIVER-WATER

It is evident that neither white artesian waters nor spring-waters such as those of the Washington Springs, nor even such as those of

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the McIntyre and Decker Springs, would greatly modify the Rio Grande waters even if a fairly large quantity of them should find their way into the river. They might change the volume of the river but they would not radically change the character of the water as we find the waters of the Poudre and other streams changed within very short reaches of their courses. If the volume of flow were the principal change effected, it would be purely a matter for mechanical measurement. The results of gaugings vary; some years they showed an increase and in other years they showed almost as decided a decrease. At this time it appears to be a matter for regret that the chemical examinations and the gaugings were not made at the same time. This, however, is the first time that the peculiar problems presenting themselves in connection with these waters have been made the subject of inquiry.

FACTS INDICATE THAT RIVER LOSES IN VOLUME AND MAINTAINS CHARACTER OF MOUNTAIN STREAM

It would appear from the results obtained that the Rio Grande, in flowing through the San Luis valley, loses in volume and maintains the character of its water as a mountain stream to such an extent that it is difficult to believe that it is receiving any significant amount of return waters, even though the ground- and drain-waters given differ in material respects from those found in or issuing from irrigated lands under cultivation in other sections.

These facts seem almost incredible and yet they are concordant with one another. First, there is a loss of water between Del Norte and the State Bridge during some months. Second, there appears to be a mean gain between Del Norte, Colorado, and Embudo, N. M.* The discharge of the river at Del Norte, is given as 711,186 acre feet, the result of 17 years' observation; at Embudo, 769,098 acre feet, observation of 14 years, a gain of approximately 58,000 acre feet. Dr. Siebenthal gives the comparative discharge of the Rio Grande at Del Norte, State Bridge and Embudo for 1900, 1901, 1902 and 1903. At Del Norte, he gives 641,017, 583,271, 315,790 and 921,561. acre feet for the respective years, and at Embudo 537,381, 572,153, 282,-032 and 1,006,600 acre feet. It will be noticed that there is a loss in three of the four years. Dr. Siebenthal gives these data in discussing the interstate aspect of the Rio Grande and shows that while the flow at the State Bridge is smaller than at Del Norte the loss is largely made up in the course of the Embudo canyon. His data show that this is the case in one year in four. This point made by Dr. Siebenthal and the geologists whom he quotes is undoubtedly well taken but this point of view is an entirely different one from that from which

*Gaugings given by Dr. Siebenthal, Water Supply Paper No. 240, U. S. Geo. Surv. pp. 13-14.

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we approach the question. The question between the states pertains to the waters collected within the water-shed by the Rio Grande—whether the impounding of these waters will militate against the interests of Mexico—and their comparisons of the flow of the Rio Grande at Embudo and at Del Norte are greatly to the advantage of the citizens of Colorado and show that the discharge of the river at Embudo is largely dependent upon water which cannot be affected by the impounding of the head waters of the Rio Grande.

RIVER ONLY DISCHARGE BUT NOT ONLY SOURCE

It is not our purpose to discuss this question but to consider the discharge of the Rio Grande from another point of view. This discharge is the only one from the valley. We have seen that the discharge at the State Bridge shows a loss, two years out of five,* and at Embudo a loss three years out of four. The discharge during the year of maximum flow was over three and a half times that for the year of minimum flow, but this was also true of the discharge at Del Norte. The Rio Grande is the only visible discharge from the valley but it is not the only discharge into the valley. While it is perfectly legitimate to consider it in this light in discussing the interstate relations of the Rio Grande waters it is misleading, as it appears to me, in discussing the water relations of the San Luis Valley. It confines our consideration to the fate of the water gathered within the water-shed of the Rio Grande as though there were no other water-shed around the valley, which is, as a fact, practically surrounded by high mountains from which waters descend into the valley.

WHAT BECOMES OF EXCESS WATER?

The discharge from the valley is, at best, probably no more than equal to the discharge of the Rio Grande into the valley. There are but two conclusions to be drawn in regard to what becomes of the excess of the discharge into the valley. It must flow out by unknown channels, or evaporate, or it is accumulating in the valley. The artesian waters do not constitute an addition to the waters of the valley, and all the irrigating water taken from the Rio Grande is already taken into consideration.

The facts that the Rio Grande loses water instead of gaining, and that the composition remains practically unchanged through a course of 60 miles through an irrigated country are entirely compatible, and the latter fact excludes the accession of any return waters, for these, even in this valley, where they seem to be of exceptional composition, would increase the amount of total solids in a materially greater degree than we find to be actually the case, and would increase the ratio of the sulfates. This is not true of the white, artesian waters, which differ mainly from the waters of mountain streams in their low content of carbonates of the alkaline earths. This difference between

* See page 13.

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the water of a mountain stream and that of these artesian wells is shown quite clearly by the analysis of the Rio Grande water taken at Del Norte and that of the Bucher or Electric Light Plant well. The Rio Grande water contained 5.46 grains of total solids per gallon, the artesian water 14.63 grains, the solids from the river water contained lime and magnesia, 22.77 percent, sodic oxid 8.48 percent; the solids from the artesian water contained, of lime and magnesia 3.23 percent, of sodic oxid, 24.09 percent. These changes are interesting for there is no question expressed by those who have investigated the artesian waters of this basin but that they are furnished by the mountain streams as they flow over or into the edges of the sand strata.

THE BROWN ARTESIAN WATERS

We have given the brown waters no consideration as yet, because we accept it as evident that, if the white waters affect the composition of Rio Grande waters in no appreciable manner, it is not probable that the brown waters, peculiar to an area more remote from the river, would exercise a perceptible influence upon its waters, especially, as there is an area in which the white artesian water occurs between the brown water area and the river

The area of brown artesian waters is designated as the Mosca-Hooper section, because these are the two important towns lying within the area.

The following analyses will show the uniformity in the composition of these waters and their marked differences in this respect from the white artesian waters, analyses of two of which have been given with the explanation that these are thoroughly typical of all the samples analyzed.

ANALYSES OF THE RESIDUES FROM BROWN ARTESIAN WATERS, HOOPER, COLO.

	Railroad Well 450 feet deep	Mill Well 750 feet deep
	Percent	Percent
Silicic acid	9.576	5.167
Sulfuric acid	0.389	0.196
Carbonic acid	34.387	36.923
Chlorin	.766	0.434
Calcic oxid	0.371	0.563
Magnesic oxid	0.113	0.179
Potassic oxid	0.107	0.456
Sodic oxid	49.688	51.766
Ferric and Alum. oxids.	0.208	0.170
Manganic oxid (br).	0.239	0.146
Ignition	(4.324)	4.267
Sum	100.173	100.276
Oxygen equivalent to chlorin	0.173	0.098
Total	100.000	100.178
Total solids, gains imperial gallon	3.92	6.7
Loss in ignition	70.56	104.3

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ANALYSES OF THE RESIDUES FROM BROWN ARTESIAN WATERS CONTD.

	Mosca Town Well	Mosca Mill Well	Hooper Mill Well*
	Percent	Percent	Percent
Silicic acid	5.537	4.821	4.160
Sulfuric acid	0.342	0.046	0.063
Phosphoric acid	0.247	0.148	0.168
Carbonic acid	37.603	37.104	37.365
Chlorin	0.425	0.148	0.470
Potassic oxid	0.982	1.148	1.433
Sodic oxid	53.077	53.665	54.045
Calcic oxid	0.413	0.651	0.282
Magnesic oxid	0.153	0.391	0.219
Ferric oxid	0.086	0.031	0.039
Aluminic oxid	0.121		
Manganic oxid (br)	0.086	0.054	0.048
Lithium, Iodin, Bromin, Titanic acid and Boric acid	Traces	Traces	Traces
Carbon or Organic matter	0.365	(1.721)	(1.814)
Sum	99.437	100.064	100.106
Oxygen equivalent to chlorin	.096	0.064	0.106
Total	99.341	100.000	100.000
Total solids, grains per imp. gal.	78.7	108.9	104.3

The sanitary analyses of the Mosca town well gave us a great deal of trouble. The results were as follows:

Total solids	1124.2857
Chlorin	6.9310
Nitrogen as nitrates	0.2000
Nitrogen as nitrites	0.0010
Saline ammonia	2.1300
Albuminoidal Ammonia	0.1750
Oxygen consumed	28.1000

The oxygen consumed was reduced from 28 to 10 parts per million by treating the water with calcic hydrate. The first two samples were taken in 1897 and the last three in 1907 and the analytical work was done by two different analysts, and yet the analyses are very nearly alike. The waters are essentially solutions of sodic carbonate colored by humus. The taste and odor of hydrogen sulfide is more or less strongly perceptible in many of the artesian waters, both white and brown. Some of the wells emit a comubstible gas; such wells do not furnish the most strongly colored waters. The waters from the deeper flows are richer in sodic carbonate, but not so strongly colored as those from a depth of about 500 feet. A comparison of the white and brown waters shows some marked differences. The white waters carry small amounts of total solids, 20.7 grains per imperial gallon being the maximum that I have found in the white waters, and there was some danger of pollution in this case, as it was from an uncased well in Alamosa. The well is now closed. The minimum that I have found in any tinted water is 25 grains per gallon in water from the

*These analyses appeared in the American Journal Sc. Vol. XXVII, p. 315.

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first flow, while the maximum is 108 grains, in water from a depth of 880 feet. The two great differences in these classes of artesian waters are, the very marked disappearance of the silicic acid from the brown waters, and the very marked increase in the total solids. The minor changes consist of an acquired color and the lessened amounts of calcium and magnesium. The color is accounted for by the presence of humus dissolved from peaty matter in the strata traversed by the water. We accept the fragments of wood appearing in refuse washed out in sinking the wells as indicating the source of the brown matter held in solution.

ORIGIN OF THE CARBONATES

I shall later attempt to explain the concentration of the sodic carbonate. Its original source may be given correctly by tracing it back to a mineral origin, but this does not account for the concentration in these waters. The "Soda Well", now closed, carried 97 grains of this salt per gallon. One can scarcely appeal successfully to the masses of organic matter that may be indicated by the humus as the source, for our most alkali-tolerant plants would scarcely yield such pure solutions of soda, unless we assume that the plants of that time were different from those of the present, which is not probable.

The source of the soda and its predominance in the area north of the Rio Grande may far more reasonably be explained by the action of water on the igneous rocks, fragments of which constitute a very large percentage of the sand occurring in the strata. The remnants of trees (wood) which are met with in making these wells, and the peaty or brown color of the water, indicate that lake or marshy conditions existed for probably long periods in this section. At the present time the lowest portion of the valley lies within this area of artesian water rich in sodic carbonate. This area has probably been the lowest portion of the valley in former times, and for the same or similar reasons as now, i. e., because the bed of what we call the Rio Grande was higher than this portion of the valley, perhaps enough higher to prevent drainage southward, and what was then lake or swamp waters were removed by evaporation.

The action of water on the plagioclase felspars present in the sand, formed largely of small, more or less worn fragments of igneous rocks, would give rise in the first instance to carbonates of soda and calcium with the liberation of silicic acid. That the carbonate of calcium was formed and separated is evidenced by the presence of very numerous kidney-shaped concretions of this substance in the sand as it was washed up in sinking the artesian wells. Sample available was from a depth of 550 feet.

The character of the white, artesian and spring waters, at the present time, is exactly such as is produced by the action of water on

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plagioclase as is also that of river water flowing over sands and boulders of granitic origin. This character is very marked in the two artesian waters given as typical of the white artesian waters of the valley.

Here we find that, approximately, one-third of the total solids consist of sodic carbonate, with relatively large quantities of silicic acid and calcium salts. The latter substances are practically removed from the brown waters. The river waters show the same fact, only to a less marked degree, and the elimination of the silicic acid and alkaline earths has not taken place. In the spring waters we find the same fact. In the water from the Washington Springs, for instance, we find a total of 5.7 grains of solids in an imperial gallon, of which, 1.74 grain is silica, 2.85 grains are alkaline carbonates and 0.98 grain is sulfates of the alkaline earths.

This process of taking sodic carbonate into solution from the plagioclase felspars is going on at this time and the only adverse question attaching itself to this view of the origin of the sodic carbonate is in regard to its sufficiency, of which I think there can be no reasonable doubt. The carbonate of calcium has been deposited in the form of small concretions and the silica may have been used in a variety of ways, perhaps to enlarge sand grains or to form new silicates. I have no knowledge of any direct proof that this latter process is going on. In the case of the Cache la Poudre water we find the whole of the silica removed on its first contact with the conditions that obtain in its plains section. It seems probable that this disappears in the formation of new silicates.

The origin of the carbonates here suggested is in harmony with the facts that we find obtaining in regard to the action of water on these plagioclase felspars, also with the composition of the artesian waters themselves. It is immediate and simple, and is suggested by the facts in the case.

LARGE AMOUNTS OF SODIC CARBONATE POURED ONTO LANDS BY WELLS

In order that the general reader may form some appreciation of the amount of sodic carbonate involved in this question, let us suppose that the "Soda Well" discharged 200 gallons a minute and that it carried 97 grains to the gallon. Such a well would deliver 5¾ tons of anhydrous sodic carbonate a month, or more than 12 tons of washing soda. Some of these wells have been flowing for 20 years, others even longer. It is true that many of these wells are only 2, 3 and 4 inches in diameter, but there are many of them, and the amount of soda yielded during the past 25 years must have been considerable.

I offered, 20 years ago, to furnish a complete analysis of any sample of black alkali found in this State without charge. I excepted

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this section, for it has long been known that there are occurrences of pure sodic carbonate within its limits. I do not know who first discovered it. Attempts have been made to prepare and market it. It matters but little to the facts in the case whether we have any explanation to offer for them or not, the facts remain just the same, i. e., that the artesian waters in this section are rich in sodic carbonate, and the people who live in this section have observed that these waters are not good for irrigation.

Concerning the use of these waters for irrigating crops, Dr. Siebenthal says: **"It seems to be pretty generally agreed, however, as the result of experience, that the dark water is nowhere as good as ditch water and that in many places it is positively harmful and should always, if posible, be used in conjunction with ditch water. Its moderate use is likely to cause a "case-hardening", or the formation of a hard crust on the soil surface. In any event, even if one application is not injurious, its continued use in subirrigation will surely impregnate the soil with alkali."***

We shall have occasion to return to this subject for a fuller consideration of the conditions and facts as they have developed during the past 20 years.

THE SAN LUIS LAKE WATER

There still remains a small body of water which is entitled to consideration. This is the San Luis Lake which presents a surface of a little more than one square mile and has an average depth of 15 feet under ordinary conditions. This is the statement usually made. I have no other knowldge as to the depth, which varies with the season and is greater some years than others. There are several lakes, but only one of them has any considerable size, which is the San Luis Lake. This lake is peculiar in that it has no outlet, though the last time that I was there I was told that it was overflowing on the west side. There was a condition of affairs at this time that I had never seen before though I have been there often. The land to the west of the lake for a distance of quite two miles I would judge, was, for the most part, under water. This water, I was informed, was from the tailings of the irrigating and drainage ditches and water flowing out of the lake. I can not well verify these statements. This lake not only has no outlet, it also has no visible inlet except at rare intervals, when the waters of the Saguache and San Luis creeks flow overland into it. I have been informed that this happened but once in 40 years prior to 1909 and I was also informed that it had happened once in 21 years prior to that time. These two statements are of course not contradictory. The persons giving the information may have referred to the same occasion. Be that as it may, it is evident that this is a rare occurrence. The Sagauche and San Luis creeks, especially the Saguache, would be classed as mountain streams and undoubtedly carry

*C. E. Siebenthal. Water Supply Paper No. 240, U. S. Geo. Survey, p. 115.

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water similar in composition to that of our other mountain streams, fairly represented by the waters of the Rio Grande which we will use for comparison.

ANALYSES OF RESIDUES FROM SAN LUIS LAKE WATER

	Sample taken 15 Oct. 1902	Sample taken 8 May, 1916
	Percent	Percent
Silicic acid	9.118	13.401
Sulfuric acid	5.801	10.255
Phosphoric acid	———	0.116
Carbonic acid	22.096	16.813
Chlorin	4.209	5.146
Calcic oxid	2.673	4.178
Magnesic oxid	5.613	4.632
Potassic oxid	13.832	8.559
Sodic oxid	35.590	28.210
Aluminic oxid \ Ferric oxid /	0.629	0.856 0.301
Manganic oxid	0.216	0.465
Ignition	1.574	(6.350)
Sum	101.351	101.162
Oxygen equivalent to chlorin	.948	1.162
Total	100.413	100.000
Total solids in grains per imp. gal	62.2	55.9
Loss on ignition in grains per imp. gal	8.2	

Sanitary Analyses of the Waters

	Parts per Million	Parts per Million
Total solids	888.5900	798.0000
Chlorin	36.1420	39.0000
Nitrogen as nitrates	Trace	0.1500
Nitrogen as nitrites	1.4000	0.0100
Saline ammonia	0.6250	0.3300
Aluminoidal ammonia	0.7130	1.0700
Oxygen consumed	31.5000*	14.1000

*The oxygen consumed was reduced to 10 p.p.m. by treament with calcic hydrate.

These samples were taken at different seasons of the year and nearly 14 years apart. I personally took both samples and remember distinctly that the lake was very low when the first of these was taken and, though I have seen this lake very often, I do not remember ever to have seen it so high as when the last sample was taken; therefore, it is probable, that these results represent the extreme differences to be met with in samples of this water. The results are remarkable, for, as I understand it, the drain ditches have been tailing their water into the trough of the valley for three or four years, and, as stated, the country for about two miles to the west of the lake was, at the

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time of taking the last sample, covered with water. This was the case to such an extent that, had I not been accompanied by a person thoroughly acquainted with the ground, I would not have ventured to try to approach the lake.

An examination of these analyses makes evident the fact that the solids held in solution differ materially from those of any water so far presented. They differ from the river waters in containing less silicic acid, less lime and magnesia, more chlorin, as much or more carbonic acid, about the same amount of sulfuric acid and very much more potassic and sodic oxids. This is particularly noticeable in the case of the potassic oxid. The differences are not such as we find in the drain- or ground-waters, nor do they correspond to the changes that we might expect as due to evaporation of the river waters. Evaporation is without doubt an important factor in the case. The evaporation from the lake surface is probably not less than 60 inches annually and must effect some changes, but we find the sulfuric acid at the time of low water less than in the river waters. The concentration of these waters is very far from the point at which any sulfates would separate due to this cause. The total solids in the lake water amount to, approximately, 8 or 12 times as much as we find in the river water. The potassic oxid is from 4 to 6 times as high in the residue from the lake-water as in that from the river-water.

There is, further, no relation between the lake and artesian waters. The differences mentioned above are even more strongly pronouncd in this case than in that of the river waters. This would be a natural inference as the source of the lake- and river-waters is evidently the waters supplied directly by the mountain streams, and still it is altogether possible that the lake-water may be directly supplied from the artesian basin, as I believe some of the springs in this section of the valley to be, the Washington Springs for instance. There are artesian wells on the east side of the lake and very close to it. The water is white, tastes distinctly of hydrogen sulfide but is an agreeable, potable water. The water furnished by the nearest well that I know of on the west side of the lake, furnishes a tinted water. These wells may, indeed almost certainly do, tap different flows. The soda lakes are close to the San Luis lake on the east and south. I hold that these soda deposits owe their origin to the brown artesian waters which come to the surface at these points and are evaporated. Such an explanation is clearly not applicable to the water of the San Luis lake. These relations are pointed out because the statement of our work on the waters of the valley would not be complete without reference to it, and also for the better reason that the water presents interesting questions.

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There are some very important questions which have not yet been touched upon, or if they have been suggested, they can be put much more plainly. We have given analyses of artesian waters from the town of Alamosa, others from the town of Mosca. The difference in altitude between these two towns is 15 feet. The intervening country is without known folds or faults, the distance is less than 14 miles, and yet the artesian water at Mosca is wholly different from that at Alamosa. This is true for all the different flows encountered at the respective places, which may be illustrated by the Electric Light well at Alamosa and the Mill well at Mosca. The former has a depth of 820 feet, the latter a depth of 780; the former is a white water carrying 14.6 grains of total solids per imperial gallon, 50 percent of which is silicic acid; the latter is a brown water carrying 104.3 grains of total solids, of which only 4.2 percent is silicic acid and approximately 90.0 percent is sodic carbonate. In 1896 I examined the water of a well 8 miles north of Alamosa, on what is given as the probable limit of the brown waters, and found that it carried 103.6 grains of total solids, almost 90.0 percent of which was sodic carbonate, with only about 0.33 percent of silicic acid. It is a question how waters of such different characteristics can occur in the same aquifers without any barriers caused by foldings or faults. These differences are found in all of the flows within these respective areas. The limits of the brown waters are not necessarily the limits of the alkaline water for the last water mentioned was scarcely colored at all. The limits of the alkaline waters have not been determined, neither has there ever been any attempt, so far as I know, to trace the alkalinity of the waters between the two sections to determine whether there is a comparatively sharp line of separation or no line at all. The amounts of solids held in solution might be used as a criterion but this has not been attempted to my knowledge. In other words, the line between the acid and alkaline waters has not been determined. It is difficult to conceive how such lines can continue to exist, for even within the aquifers themselves there must be some diffusion, especially when so many openings have been made, which must establish some movement of these waters. A single 2- or 6-inch vent might not be of much significance, but when thousands of vents—upwards of 5,000—even if they are not greater than 2 inches in diameter are furnished, one would expect a considerable aggregate movement within these aquifers which might tend to bring about a mingling of these waters and to eliminate any sharp boundary. No observations at all have been established on these points so far as I know and it is wholly unknown whether the limits of the alkali water may have changed during the past 20 or more years. This period of time is not too long, for there were as many as 2,000 wells estimated to have been put down by 1891.

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AGRICULTURAL FEATURES OF THE QUESTION

The strictly agricultural features of this problem are interesting and also involve a large territory. The facts in the case are simple but most conclusive in their character. The Hooper-Mosca section was, in 1893 to 1896, probably the greatest wheat producing section of the State. In 1916 this section was very largely non-productive, between 300,000 and 500,000 acres of land having long since been allowed to go back into greasewood and chico. The flouring mill at Mosca was torn down some years ago and the one at Hooper has been dismantled recently as a flouring mill after running many years on an inadequate supply of grain. This mill, I am told, may be continued as a feed mill. These are a few of the bald facts.

I do not know that anyone has ever formulated a statement of causes to account for this condition. It has generally been assumed that it is due to a high water-table. On this basis, drainage has been advocated strongly and with much confidence by a number of persons. In fact, much capital has already been invested in drainage projects and a number of proposed projects have not been carried out because of the difficulties encountered in financing them.

SUBIRRIGATION HAS CAUSED WATER-LOGGING

The system of irrigation practiced almost exclusively in the valley, i. e., subirrigation, has hastened the water-logging of the lower lands; of this there can be no question. In this system it is the practice to keep the water-table within a few inches of the surface during the whole, or most, of the season. I have not personally investigated the height of the water-table usually maintained, so I cannot make definite assertions in regard to this point, but inquiry has elicited the information that this depth varies from 12 to 24 inches. The latter is the greatest depth assigned to it. I recently made inquiry of a prosperous ranchman in regard to this point. He stated that he kept the water within 12 inches of the surface. The crops grown with this high water-plane were alfalfa, peas, oats, potatoes and wheat. This man asserted that his teams would mire on his land most of the time. I made inquiry in regard to this man's standing in the community and the results obtained on his lands. I learned that he was a man of influence and that he had probably told me the truth about his crops, both in regard to growing conditions and yields. I inquired further in regard to the depth to which this water-table fell during the winter when irrigation was not being practiced. The answer was prompt, that it varied, but that in none of the land did it fall to more than 3½ or 4 feet. I have bored, or dug with a spade, holes in other wholly unproductive sections of the valley during the irrigating season, and found no such high water-plane assigned to the lowest plane

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for subirrigated land, 24 inches. In July of 1916, I dug a hole in unproductive land near Mosca and found the water-table 36 inches from the surface. Later a sample of water was obtained from this place and a more careful measurement made of the depth of the water-plane, 37 inches. Southwest of Alamosa, I made a boring and did not find free water at 4 feet. It is difficult to reconcile the success generally had with subirrigation in which the water-plane is intentionally held within a short distance of the surface and the failures on land with a lower water-plane, if excessive water be the cause of unproductiveness as is claimed. Facts such as those just cited lead naturally to a doubt in regard to the correctness of the assertions made in this connection.

Other facts lead to a similar conclusion regarding the insufficiency of the high-water plane to explain the cause of the unproductiveness of these lands. One of these facts is the results being obtained by flooding without other than the natural drainage of the land. In some instances a fair degree of success has been obtained with alfalfa by this method, just as marked as by drainage, perhaps more so. The trouble is not to maintain the plantation of alfalfa but to get the seed to come up and to establish the young plants. When once established the alfalfa does fairly well, some of it very well. These facts indicate a trouble at the surface of the soil and not an excess of water that drowns the plants. Some ranchmen are seriously considering these facts. I do not know to what extent such views prevail among the people but some of them do not accept the seepage theory as the principal cause of the trouble which prevails throughout many thousands of acres—from 400,000 to 500,000

I do not wish to leave the impression that I have not found any cases in which the water-plane in unproductive land was not higher than 36 inches. I have found it very near the surface, but nowhere within 12 inches, that I can recall. I have found the water-plane high, within 18 inches of the surface, in very unexpected places and under conditions which we would judge to be favorable for drainage, i. e., in sandy soil with a good fall in one direction. This instance is interesting for several reasons. It was a desert claim. Irrigation was effected on a small scale by artesian wells. The person who had taken up these claims had made an honest effort to comply with the government's conditions to obtain a patent to the land. He had failed according to the authorities and the patent was withheld. The party had sunk 17 wells on this tract of land. He had diked several pieces of it and turned in his artesian water. The first year or two he had good results, the next 4 or 5 years everything failed and the land was entirely barren during the past summer. I cannot state that these diked sections were seeped. I think that they were not, but other areas,

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some occupied by alkali grass, others by clumps of greasewood, were seeped. The water-table in some land near the house was within 18 inches of the surface. This party stated his case as becoming worse the more water he used. He could not grow anything without irrigation and to irrigate with this water for one or two years, was to make it impossible to grow anything. Fortunately, the government representatives sent to examine into the facts of the case, realized that this party had made an honest effort to meet the requirements of the law and that his failure was due to some cause for which he was not responsible. We have the following facts: The land had produced good crops for one or two years on the application of water; it then became unproductive, and a comparatively small well sufficed to seep a considerable area of this desert claim.

The water furnished by the wells that I saw was of good quality, it was a white water carrying 5.5 grains of total solids to the imperial gallon, 37.27 percent of which was silicic acid and the rest was essentially sodic carbonate. This is very similar to the water furnished by the Washington Springs and the Widow Smith's Well. The sample of water taken was from the second flow.

Two samples of alkali were gathered from different parts of the tract, but neither one very far from a well. These wells have been flowing 5 or 6 years. The composition of these alkalis is unusual for our state and for the San Luis Valley as well. Analyses of alkalis which appear as efflorescences from localities pretty well distributed, and I believe representative of the general conditions in the Valley, have been given in the preceding pages. These consist chiefly of sulfate of soda. The soil extracts which are given are from various sections and indicate that it is usual to find the same salts in these as in the efflorescences which occur on the surface. The exception to this statement is found in the water-soluble from a soil sample, taken amid greasewood bushes in which we find sodic carbonate making up 25.4 percent of the 1.935 percent of water-soluble. The efforescent alkali, corresponding to this sample, carried 8.3 percent of sodic carbonate. This land was once under cultivation, but how long it had been occupied by greasewood at the time this sample was taken, I do not know.

GREASEWOOD INDICATES PRESENCE OF SODIC CARBONATE

While I am not prepared to reject wholly Prof. Hilgard's theory that the debris from these plants enrich the soil in sodic carbonate, I am strongly inclined to think that in this valley the growth of greasewood is indicative of a soil condition favoring their development and that their presence is a result of the prevalence of this salt in the soil, perhaps in such quantities as to render the soil already an inhospitable one to most cultivated plants, and for this reason the *sarcobatus* becomes the predominant vegetation, for it can endure the sodic carbo-

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nate. This in no wise asserts that this plant cannot or does not flourish in other soils. The most vigorous samples of *sarcobatus* plants that I remember having seen were growing at the edge of a kitchen garden with which no one could possibly find any fault on account of any lack of luxuriant growth. But, I think, that it is true in the section of the San Luis Valley land had in mind, that the presence of this greasewood indicates a strongly alkaline soil in which sodic carbonate forms a relatively large proportion. On a preceding page we have given an analysis of the water-soluble portion of such a soil and find that sodic carbonate makes up a little better than ½ of the total, while in the alkali that effloresced from this soil, about 1/12 of the salts soluble in water was sodic carbonate.

WHITE ALKALIS NOT INJURIOUS TO CROPS

My judgment relative to the injurious nature of our white alkalis, the efflorescences of which are designated by this name in this State, is that they are so good as harmless in any quantities in which they actually occur. It is a matter for regret that there has been so much said about the injurious effects of these alkalis that there has grown up a general belief in their injurious properties. These alkalis in Colorado consist usually, of the sulfates of soda, lime and magnesia, usually with small quantities of chlorids and carbonates. I have grown beets carrying from 14 to 19 percent sugar and yielding from 9 to 19 tons per acre on land the top 2 inches of which carried 3.5 percent of water-soluble salts. I measured incrustations formed on this land which attained a maximum of more than ½ inch. I have seen so many other instances of extremely alkaline land, in so many different sections of the State, on which excellent crops were produced, that I am convinced after 23 years of observation of this particular subject, that our ordinary white alkali is not sufficiently abundant in any of our ordinary soils to deserve any serious consideration. I have elsewhere stated, apropos to this subject, that on one occasion I measured alkali incrustations 3/16 inch thick under the leaves of beet plants and on digging found the ground water within 18 inches of the surface. This crop of beets was irrigated with seepage water, carrying 259 grains of total solids to the gallon. I was interested to learn what the harvest of this crop revealed, and wrote to the officers of the factory which handled the crop. They kindly gave me their record—9 tons per acre one year and 10 tons the next, with 16 and 16.5 percent sugar in the respective years. There was more of this alkali land which yielded much larger crops and slightly better beets. I saw a crop of wheat grown on land that I, at first, thought wholly unfit for wheat-growing, but the yield was 60 bushels per acre. Such facts as these can be duplicated in many sections of the State and are so patent that one cannot justly make the unqualified assertion so often met with, that the alka-

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lis are injurious and have rendered the land worthless. I undertook some 15 years ago to ascertain the maximum amount of alkalis that might be present in an irrigating water without becoming injurious to the crop. I found the maximum so high that its ascertainment might have been interesting, but was of no practical value. The 60-bushel crop of wheat referred to in this paragraph was irrigated with seepage water that carried nearly 500 grains of ordinary alkalis to the imperial gallon, and the land was already rich in these salts. I took a sample of this soil during the summer of the preceding year, selecting a spot in which corn had almost failed and obtained 4.67 percent soluble in water, of which 69.0 percent was sulfates and 19.0 percent chlorids. This of course was the surface soil, but this is the portion invariably considered when this subject is spoken of. It is true that sometimes the alkali in a certain depth of soil is mentioned, but this is not usually the case.

UNPRODUCTIVENESS DUE TO SOME CAUSE OTHER THAN ALKALIS

When an ordinary alkali land is unproductive, or practically barren, as some of the San Luis Valley land is, there is some other condition contributing to the unproductiveness rather than the ordinary alkalis. Too much water is sometimes an efficient cause, but my observations in the field, as well as my experience with beets in thoroughly seeped land, make me rather more cautious in making assertions in regard to this as a cause of unproductiveness than many persons are. The practice of subirrigating may be unreasonable, but if the statements of those practicing it be in any reasonable measure reliable, the results obtained throw doubt on the correctness of much that is said regarding the subject of a high water-plane. Their practice may amount to water-culture on a large scale, be it so—*they raise the crops.* The fact is probably this; that parties expected to give an explanation, knowing, as every other person knows, that something is wrong when large areas formerly productive become unproductive, and feeling impelled to assign a cause, practically adopt the irresponsible view that they might as well assign it to alkali or to a high water-table as to anything else, because these are visible, and it is difficult to prove that they may not be the cause. The assertion, especially concerning the common white alkali, is of little value by whomsoever it may be made, while the evils due to seepage have been well ridden in our country for some years. There is no question, but that seepage is a real, and a serious problem, and one that is likely to become more so, but it is possible to attribute results to seepage for which it may be only indirectly, if at all, responsible. There may be troubles in a seeped country due to other causes than the seepage and which drainage may or may not alleviate.

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It is well in this connection to state the preceding facts, that there may be no doubt about the value that I believe attaches to the assertions very generally made, particularly in reference to the alkalis, as the term is commonly used among us, where it means the ordinary white efflorescences on our soils.

I stated that the samples of alkali gathered on the desert claim were of an unusual type. The analyses of these samples show the presence of 14.75 and 40.368 percent of sodic carbonate respectively. The full statement of these analyses follows:

ALKALIS FROM A DESERT CLAIM

	I	II
Calcic sulfate	1.489	3.781
Magnesic sulfate	0.367	1.065
Potassic sulfate	2.874	4.978
Sodic sulfate	26.162	30.807
Sodic carbonate	40.368	14.750
Sodic chlorid	20.938	40.161
Sodic phosphate	0.959	0.391
Sodic silicate	4.271	2.866
Ferric and Alum. oxids.	0.082	0.340
Manganic oxid	0.202	0.265
Excess of sodic oxid...	2.288	0.596
	100.000	100.000

The soil where sample II was taken was not very badly encrusted and contained only 9.2 percent soluble in water, but the sodic carbonate present amounted to 1.35 percent of this surface portion.

The presence of such large quantities of sodic carbonate and the known toxicity of this salt to ordinary vegetation, were suggestive of the cause of the failure of the grain or the unproductiveness of the plots after the second year's irrigations. I have already stated that we have examined the water from the second flow and found it excellent water from the ordinary standpoint. This water carried 5.5 grains of total solids per imperial gallon, of which essentially 37.0 percent was silicic acid and the rest sodic carbonate. Such a water is apparently a good water, but the experience of this settler was that the more water he applied, the worse the conditions became.

The evaporation from a free water surface at this place is, according to the best information that I have, 60 inches or rather more per annum; taking the evaporation from a soil surface at 36 inches and neglecting the loss by percolation which, judging by the readiness with which local water-logging may be effected, seems at most very small, even such water might be an efficient, contributing factor in bringing about unproductiveness in the soil and justify the hard fact stated by the settler, "the more water I apply the worse I'm off". Even this water will deposit 354 pounds of sodic carbonate per acre per annum under the assumed conditions. It is not at all improbable

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that the sodic carbonate found in these alkalis came, principally at least, directly from the evaporation of this artesian water, for these wells had been flowing for more than four years. This water belongs to the white artesian waters. A short distance from this, about ¾ of a mile, a well sunk to irrigate some meadow land yields a strong flow of brown water. Concerning the effects of this water there is no room for argument, for it had killed the grass wherever it flowed over it. The water from this particular well was not analyzed, but we assume it to be similar in composition to other brown water from the same flow.

It is a very generally admitted fact that even the white artesian waters are not good for irrigating purposes. The almost universal testimony is that ditch or river water is preferable. Further, it is a common observation that the brown waters are not at all good for this purpose but that they are bad, for they kill some plants and cause the ground to become hard and it is then impossible to get alfalfa or other crops to come up and grow.

SEVERAL DISTINCT QUESTIONS INVOLVED

The agricultural problems present several distinct questions, each one of which may be of greater or less importance. The first question is in regard to the effects of our ordinary alkali salts.

That this question should be the first one suggested by the ordinary inquirer is natural, for the occurrence of these salts is abundant and sufficient to coat large sections of the valley with a covering, quite literally, as white as snow.

I have already stated my personal conviction, that this of itself is not a very serious matter. This conviction is based upon cultural facts and not on a theory to explain something.

The second one is the question of seepage. This is *per se* a more important question, perhaps, than that of the alkalis. Unfortunately this condition seldom occurs with us without being accompanied by the first question. The results of practicing subirrigation for many years raises serious questions in connection with the problems directly involved, to which general principles scarcely apply. In order to indicate more fully, but not to argue the question, it may be stated that in one section of the valley excellent crops, alfalfa, peas, oats, potatoes, etc., are grown with a water-plane intentionally kept nearer than 24 inches of the surface, sometimes as near as 12 inches, while other sections are only partially productive or wholly unproductive, with a water-plane 36 or more inches below the surface. The productive, subirrigated land is very far from being free from alkalis. How abundant they may be I do not know.

A third question, one presenting itself in the case of the desert claim, applies to a very large section, but not to all of the valley; this

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question is: Has the carbonate of soda, or black alkali, become so abundant as to be the determining factor in the unproductive condition of the area had in mind—in this case, the Hooper-Mosca section, an area coincident with the brown, artesian waters?

A fourth question pertains to this and to other sections of the valley as well: This is the question of the development of nitrates in injurious quantities. I have seen at least one tract of 640 acres on which the pea crop was wholly destroyed due to the presence of excessive nitrates. I heard of a second tract of 80 acres which was destroyed by the same agent. The people attributed these failures of the crop to the grasshoppers, though the peas that I saw either had not come up at all or had turned yellow and died without having been touched by the hoppers, if indeed there had ever been any hoppers there.

This general statement of the case by no means presents all of the problems of the valley, but these are the big, patent ones.

The United States Land Office sent a party out to investigate claims on which patents had been withheld for one cause or another. Some of these investigators recognized that there was something radically wrong in many of the cases. These settlers are not all dishonest men, trying to get patents to land for unworthy purposes, and yet they have been unable to satisfactorily comply with the government's requirements, as in the case of the desert claim mentioned in preceding paragraphs, or have abandoned the claims after having spent several years and perhaps all of the money that they have been able to get in order to make a success of them. In conversation with a member of this party, I found that he was seriously considering these questions. The trend of his argument was that men would not spend two or three thousand dollars and four years of their lives, perhaps with their families, on these claims, and then fail to comply with the government's reasonable demands or abandon the claims altogether, unless there was something wrong, for which an adequate explanation had not yet been found. I believe that his conviction was an honest one, that the government ought to protect such parties against the possibility of undertaking to prove up on such lands without full knowledge of the difficulties, or of giving them a full chance to try if they wished to knowingly undertake it.

It was not our intention to take up these agricultural features in this bulletin, but the growing conviction of their unusual character, their seriousness, and, as I believe, their intimate relation to the character of the artesian waters of the section justify me in giving the outlines of the salient problems presenting themselves. Up to the present time these questions have been dealt with only as they were incidental to the chief work presented, i. e., a study of the hydrology of the valley.

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A REVIEW OF THE HYDROLOGICAL FACTS

In this work we find that the river water is characterized by a composition peculiar to mountain waters which is the result of the action of pure water on the rocks of the mountains, or the gathering grounds of the rivers. There are but comparatively few minerals concerned in the reactions which it is necessary to consider in this connection, in fact, we can confine our consideration to the plagioclase felspars, because these are the minerals that play the predominant part in these reactions. It is scarcely necessary to state that it does not matter whether the felspar constitutes a part of a metamorphic or an igneous rock, though its association and physical condition may affect the rate of alteration. Our white artesian water, especially from the shallower flows, differs but little from the mountain water, in fact, the water from a depth of 923 feet from the Bucher Well at Alamosa, carries only about three times as much mineral matter in solution as the Rio Grande water taken just above Willow Creek, but otherwise it is similar, exchanging lime for soda.

The residue from the water of this deep well contains 50 percent silicic acid, 14 percent carbonic acid (CO_2) and 23 percent sodic oxid, with some lime. The river water contains 43 percent silicic acid, 13 percent carbonic acid and 20 percent lime with 6.8 percent soda. The great change here is the exchange of lime for soda. When we pass from the area of white waters to that of the brown waters we find a further change in the elimination of the silicic acid and an increase in the amount of soda present with an almost complete elimination of the lime. The brown color is accidental for we have almost colorless water from this same area very rich in sodic carbonate. These peculiarities of composition are maintained by the different flows. The shallower flows may not be so deeply colored nor so heavily charged with mineral matter, but the composition of the mineral matter has the same peculiarities—absence of silicic acid and lime with sodic carbonate very strongly predominant. This is true of shallower wells, 15 feet in depth, which yield a white water carrying about 20 grains of total solids to the imperial gallon. Fifty percent of this was found to be sodic carbonate. The sulfates were not determined in this sample. This is an agreeable, cool water used for domestic purposes. The excellent quality of this water seems remarkable, for the whole country in this section is quite alkaline, in fact, there is a piece of land within a short distance of this well that is in very bad condition and white alkali is very abundant. The prevalent unproductive condition of the land and the area of sodic carbonate-bearing artesian water, usually brown in color, are nearly if not altogether coincident.

It is true in both areas, that of the white acid artesian waters and that of the brown alkaline waters, that the deeper flows are richer in

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total solids than the shallower, but the increase in the brown water area is much more marked than in the white water area. In the latter area this increase is from about 5 grains to 15.9 grains per imperial gallon; in the former, the brown-water area, the first flow carries about 22 grains which increases to 108 grains per imperial gallon in the deepest flow examined. For the present, we may consider the source of the carbonate to be the country itself, i. e., we may consider it as existing throughout this whole section as ready formed sodic carbonate without any regard to the original source from which it was derived or the agencies contributing to its formation. I have previously indicated my belief in its formation by the action of water on the sands consisting very predominately of grains of igneous rocks and possibly in a large measure to the evaporation of such water within this area due to a lack of drainage throughout a long period. It is, however, much more convenient for our present purpose to adopt the preceding statement—that it occurs, already formed, in the strata of this section of the valley. This agrees with the fact that if you start at Alamosa and go northward, the water increases both in alkalinity and the amount of total solids contained, until you get a little north of McGinty; from here to Hooper it remains about the same. It is understood that these statements are, in a sense, general in character, for, at the present time, it is practically impossible to obtain reliable information relative to the depth from which a well may be delivering water and general statements are the only ones that can be made, as the flows taken may not be the same.

If we start at Center near the western rim of the artesian basin and sample the waters eastward to Hooper, we find a very similar series of results—an increase in both the alkalinity and total solids.

While the foregoing statements are, in a sense, general ones, they are based upon two series of samples taken, as suggested, from Alamosa northward and from Center eastward to Hooper. In a few instances we can ascertain the depth from which the water rises, but in the majority of cases we cannot get satisfactory information. Another difficulty is that but few of the wells are so cased that we get the water from a definite flow. In the instances in which the depth of the well is known, I shall give it, in other cases I can only designate the wells as shallow or deep.

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ALKALINITY OF ARTESIAN WATERS

Locality	Depth of Well	Sodic Carbonate in parts per Million
Alamosa	923 feet	68.0
Alamosa	820 feet	68.0
½ mile south McGinty	Deep	795.0
North of McGinty	Deep	1070.9
2 miles north McGinty	Deep	1171.3
2 miles north McGinty	Deep	1229.6
4 miles north McGinty	Shallow	371.0
Mosca	780 feet	1388.6
Mosca	500-600	1003.0
2 miles north Mosca	Shallow	318.0
3 miles south Hooper	Deep (780?)	1446.9
2 miles so'east Hooper	Shallow (2d flow or deeper)	593.6
1 mile north Hooper	Shallow (1st flow)	371.0
Hooper	750 feet	1356.0
Center	200 feet	74.2
3 miles east Center	Shallow	74.2
4 miles west Hooper	375 feet	79.2
4 miles west Hooper	739 feet	477.0
2 miles west Hooper	Shallow	212.0
1 mile west Hooper	Shallow	291.5
Hooper	450 feet	840.0

The samples from Alamosa to Hooper represent water taken in an almost straight line beginning south of and outside of the alkaline area and running due north to approximately the center of the area. The samples from Center to Hooper represent a line beginning west of and running due east to the central portion of the area.

In addition to the above data the results obtained on examining the water carried by the Sylvester drainage ditch will give an idea of the character of the ground-water in the line of the latter samples, Center to Hooper. A sample of this water was taken two miles west of Hooper and carried 159.0 p.p.m. of sodic carbonate; another sample was taken as tailing water one mile east of Hooper, and this carried 227.9 p.p.m. A shallow well, 15 feet deep, used for domestic purposes, carried 159.0 p.p.m. of sodic carbonate. The depth of the Sylvester drainage ditch where the sample was taken, west of Hooper, was probably 8 feet.

The data herewith presented to exhibit the alkalinity of the artesian and even surface waters of the section under discussion are sufficient to show that we are justified in presenting them for serious consideration in connection with the unfavorable agricultural conditions that prevail throughout this section of country, which, as I have previously stated, is co-extensive with the area of alkaline water. I do not know the exact outline of this area, but there are probably at least 400,000 acres of land affected by these conditions.

The quantities of sodic carbonate given in the above statements may not convey any definite idea to some readers, therefore it may be

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advisable to state how much they may mean. The annual evaporation from a free water surface in the San Luis Valley may be taken as 60 inches, and from a soil surface as 30 inches. The drainage water carries 159 p.p.m., or each million pounds of water carries 159 pounds of sodic carbonate. If 3 acre-feet of such water were evaporated to dryness on an acre of land, and the whole of the carbonate were left on the surface, it would mean the deposition of 1,300 pounds of sodic carbonate, which would add, if thoroughly mixed through the top foot of soil, 0.03 percent of sodic carbonate. In experimenting with beet seedlings years ago, I ascertained that the presence of 0.05 percent of this salt in the soil was injurious and could not be exceeded without killing the seedlings. This is the importance of the preceding figures, i. e., the ground- and drainage-waters, and all of the artesian wells in this area contain sodic carbonate. The brown artesian waters are, for all purposes proper to consider at this time, simply weaker or stronger solutions of this salt. This is true to such an extent that we illustrate it by the following statement: If a gallon of brown water contains 70 grains of salts in solution, 63 grains of these 70 grains are sodic carbonate or black alkali. The presence of this salt is a fully adequate and satisfactory explanation of the fact observed by many ranchmen that artesian water is not so good for irrigating purposes as ditch, or river-water, which is a conservative statement, for many of them have observed that the brown waters are fatal to vegetation. The water from one of the wells mentioned in the preceding table flowed over some land for a few months and the owner told me that it was several years, four years I think, before he succeeded in overcoming its effects.

I have previously stated that, for our view of agricultural conditions, we can consider this black alkali, sodic carbonate, as existing in strata of this country to a depth of at least 900 feet, for we find the water of cased, artesian wells becoming richer in this salt till we gain this, approximately our greatest depth. We certainly do not need to concern ourselves about the more remote origin of the salt so far as it pertains to the agricultural questions of the section.

UNFAVORABLE CONDITIONS PREVAIL WHEREVER WATER IS ALKALINE

An important consideration in this connection is the actual soil conditions that obtain. If these contradicted the views set forth, we would certainly conclude that their presentation was worse than unwise. *It is, however, a fact that the unfavorable agricultural conditions and the alkaline character of the water are coincident in their occurrence, which is of itself very suggestive.*

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SOIL SAMPLES TAKEN TO PROVE RESULT

In order to prove this question further, two series of soil samples were taken along the same lines that the water samples were taken. It is readily foreseen that soil samples taken to represent so long a stretch of land, the lines aggregating more than 30 miles, will vary greatly and it would be no matter for surprise if some of them seemed to contradict the statements made. This, fortunately, is not the case, for we find that our results agree very well with the facts as seen in the field.

In the following statement of results, I shall give the conditions of the land as of more interest than the locality and state the results in parts per million of air-dried soil.

Sodic carbonate present to the extent of 400 p.p.m. is injurious to most crops and I doubt whether any cultivated crop can endure as much as 500 p.p.m. I think that it is perfectly safe for the general reader to use these figures as guides in judging the results given in the following table:

ALKALINITY OF SOIL EXTRACTS

Condition of land or crop	Sodic Carbonate (Black Alkali) in parts per million
An old "gone-back" ranch	865.0
Land in bad condition, crops failed	375.0
Land barren for some years	722.0
Land barren	925.0
Barren, sandy soil	5103.0
Alfalfa field, stand good	144.0
Old alfalfa, stand medium	200.0
Alfalfa field, stand good	259.0
Sandy soil, alkali grass, some sweet clover	121.0
Diked and flooded soil	109.0
Sandy loam, uncultivated	253.0
Oats, a failure in 1916	609.0
Deserted land	200.0
Wholly unproductive, though under good treatment	510.0
Wholly unproductive and has been for many years	3222.0
Land just surfaced	200.0
Flooded 1916, planted to rye, poor stand	398.0
Flooded 1916, planted to rye, not much living	410.0
Planted to peas 1916, died	633.0

The preceding samples represent both good and bad conditions as they are found throughout this area.

Unfortunately, the problem, like most of our agricultural problems, is not a simple one, for there are several factors playing their respective parts. The one here pointed out, sodic carbonate, is, without doubt, the principal one affecting the conditions in this area, though it has not previously been pointed out, or even given serious recognition. Excessive water alone has been charged with the ruin of the land and drainage urged as its greatest need. I am among those who do not believe this.

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DRAINAGE NOT THE MAIN PROBLEM

That our ordinary crops, oats, wheat, alfalfa or potatoes, cannot be successfully grown with the water-plane an inch above the surface, no one doubts, and lands that become filled with water to such an extent as this should be provided with an outlet for the excess water. This can be effected by surface drains. The practice of subirrigation, under which crops are grown with a water-plane maintained within 18, or even 12 inches of the surface, gave my ideas on aeration, etc., a decided shock at first. While some drainage is necessary, this is not the main problem to be solved in this section. In a great big sense, the problem has been, for a period extending back to the draining of the old lake and the building of the bed of the Rio Grande, a drainage question.

HEIGHT OF BED OF RIO GRANDE CAUSE OF EXCESS SODIC CARBONATE

I believe that the sodic carbonate owes its origin to the fact that the drainage south has been no better since the valley itself was formed than it is now and for the same reason as now. The bed of the Rio Grande has never been cut down so as to let the water north of it drain southward out of the valley. The efficiency of this simple cause to account for the concentration of sodic carbonate in this area to the extent that we find it, is impressive on a little consideration. Under this condition, the water-plane has always been high in this section of the valley. Evaporation has gone on rapidly from the surface of the land at all times. Assuming that this evaporation has been 3 feet per annum over an area of 500,000 acres, we have 1,500,000 acre-feet of water. Taking 720 acre-feet as equivalent to a flow of 1 second-foot for a year, we account for a discharge of 2,000 second-feet of water into the territory. The evaporation of 1,500,000 acre-feet of mountain water, carrying only 2½ grains of sodic carbonate in each imperial gallon, will deposit 145,500,000 pounds of sodic carbonate, or 291 pounds on each acre which must remain within the area if there be no drainage to remove it, so there would be an accumulation of this salt just in proportion as this drainage was inadequate. In this sense the whole situation resolves itself into a drainage problem, but no one has heretofore suggested this question.

There are intelligent men in the valley who appreciate that the water, *per se,* is not the most important question that they have to deal with. Many of them have become convinced that the liberal application of water to the surface, so long as there is space enough between the water-plane and the surface of the land to let the water applied pass a few inches below the surface, ameliorates conditions materially though the water-plane has not been lowered. They know that this is only a palliative, but it enables them in some cases to establish a crop.

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alfalfa for instance, which when once established may tolerate the conditions.

APPLICATION OF GYPSUM WOULD BE HELPFUL

The important question is, Can the ranchmen ameliorate these conditions? They are proving that they can by diking and washing, which, to the present time, has proven the most effective means of reclamation. A still more effective measure would be the application of land plaster, ground gypsum, which occurs very abundantly within the State. The amount of sodic carbonate in most of the surface soil, is not so abundant that the cost of the land plaster necessary to correct the alkalinity would be prohibitive; in fact, the cost ought to be very moderate. The most serious item would probably be haulage or freight owing to the location of the valley between high mountains. If, however, the use of this material should prove to be sufficiently beneficial, as I firmly believe it will, proper organization of the users can undoubtedly bring about the production and transportation of this material to the valley at a very reasonable cost. It would be greatly to the advantage of the railroad, the Denver & Rio Grande for instance, to encourage this development. I believe that the production of the land plaster ought to be a community undertaking, and also all transportation arrangements, if the most extended and beneficial results are to be obtained, for private production will look principally to private profit, whereas the amelioration of conditions in this section, to such an extent as to restore from 300,000 to 500,000 acres of land to a condition of productiveness which it formerly possessed, but which it has almost entirely lost, is a consideration worthy of the united effort of all the parties concerned.

The facts given at the beginning of this discussion, to-wit, that one large flouring mill has been torn down, that a second one has recently been dismantled, that an elevator still standing, has not been used for its legitimate purpose for years, that the towns have dwindled instead of grown, that homes have been deserted, to which remnants of fallen houses still bear witness, and the lands have been permitted to go back to the native vegetation, chico and greasewood, ought to constitute a sufficient appeal for the united and beneficial effort of the whole community. Further, the State or the Government, for the latter is still largely interested, ought to devise some effective measures for the protection of the interests of both the individual and the public against those of selfish private enterprise. Such effort and protective regulations ought to be capable of accomplishment, but it is, perhaps, useless to hope for such a consummation.

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SUMMARY

The Rio Grande flows for about 60 miles through the San Luis Valley without any considerable change in the character of its waters.

The flow of the river diminishes rather than increases in its passage through the valley.

There are only a few streams having a visible discharge into the Rio Grande.

The drainage is practically out of the Rio Grande into the valley, instead of out of the valley into the Rio Grande.

The ground-waters of the valley retain the characters of the mountain waters in a noteworthy degree.

The ground-waters, though retaining some of the features of mountain waters, have their own characteristics which are pronounced enough to affect those of the Rio Grande water if any significant volume of them is mingled with it.

The alkalis, i. e., salts that collect in the surface portions of the soil or appear as efflorescences, are of three types which are not further discussed.

These types are:

Plain sulfates, soda and lime being the predominant bases. This type is the predominant one.

Sulfates and chlorids. This type is not abundant though it is well distributed.

A type in which sulfates and carbonates occur. The occurrence of this type is for the most part confined to the area north of the Rio Grande.

Solutions of these alkalis do not find their way into the Rio Grande in sufficient quantities to noticeably modify the composition of its water.

The valley is an exceedingly large artesian basin, but the waters are of two characters. Those of the southern portion and the rim of the basin are white and carry an excess of acids. Silicic is especially high, while those of the northern interior portion of the basin are alkaline and usually brownish or brown in color.

The white artesian waters, especially those flowing from shallow wells, from 75 to 300 or even more feet, are very similar to river or mountain water and would simply increase the volume and would not change the character of the river-water if they mingled with it.

The brown water is free from silicic acid and contains so good as no salts except sodic carbonate.

This character of the brown waters is the same for all flows from the shallowest to the deepest examined, 880 feet.

The deeper flows increase in the amount of salts held in solution without any change in their character.

This increase was from 22 grains to 108 grains in each imperial gallon.

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These waters would change the character of the river water if they mingled with it, which they appear not to do.

The brown color is accidental and is due to peaty material dissolved out of the aquifers themselves. The presence of fragments of wood obtained in sinking the wells and the deportment of these waters when submitted to sanitary analysis is taken as proof of the peaty nature of the color.

The presence of peaty substances and wood in this area is interpreted as indicating that this portion of the valley was, in former times, low land and probably marshy, i. e., poorly drained.

The sodic carbonate is considered as originally coming from the mineral constituents of the rocks furnishing the sands and clays that form the strata now composing the floor of the valley.

The changes necessary to remove the silicic acid and lime from the mountain waters are simple. The small concretions of calcic carbonate met with in the sand from the strata passed through at 550 feet indicate simple precipitation as the method of removing the lime.

As the drainage of this portion of the valley has probably been just what it is now for the whole period of the existence of the valley with but little or no change in its water supply, evaporation alone is considered adequate to account for the concentration of the sodic carbonate that we find in this section.

Evaporation at the present time is sufficient to add 145,500,000 pounds of sodic carbonate to this section of the valley yearly. This is on the supposition that the mountain water carries 2½ grains of sodic carbonate in each imperial gallon, or 10 pounds of water evaporated.

The present agricultural condition of this section of the valley is due to the accumulation of this salt, black alkali, rather than to an excess of water.

Local surface drainage is necessary in many small localities.

The evaporation from the area involved is equivalent to an inflow of 2,000 second-feet throughout the year. This is probably a larger amount than this section of the valley actually receives, except for a very short period in the spring of the year when the direct overland inflow may equal or possibly exceed this amount.

The San Luis Lake water is peculiar in its composition and unlike either the river- ground- or artesian-waters.

The deposit of sodic carbonate east of the San Luis Lake is probably derived from the evaporation of the brown artesian water, and has no connection with the lake.

The conditions which have determined the character of the brown artesian waters are still active in determining the agricultural features and questions of this section of the valley.

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The question of black alkali in this section is in places further involved by the occurrence of nitrates.

The conditions which obtain and are inimical to vegetation can be ameliorated by rational irrigation, chemical treatment of the soil and surface drainage where needed.

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"BLACK AKALI" IN THE SAN LUIS VALLEY

By
WM. P. HEADDEN

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"BLACK ALKALI" IN THE SAN LUIS VALLEY

By

WM. P. HEADDEN

Bulletin No. 230 of this station, entitled "Rio Grande Waters", gives as full a statement of the water conditions peculiar to the San Luis Valley as we are able to present. The work on this feature of the valley has extended over a number of years. There are a great many features of the subject which are not of special interest to the general farmer or even to those interested in the lands of this valley, while there are others of vital importance to the ranchman, but of less interest from other points of view.

AGRICULTURE OF VALLEY RETARDED FOR A NUMBER OF YEARS

It is known to everyone acquainted with the irrigation of the valley since the early nineties, that at one time the section of the valley about Mosca and Hooper was a most remarkable wheat producing country. Mosca, for instance, was a thriving town with a large flouring mill, an elevator and a flourishing business. This prosperity passed a number of years ago; the elevator is unused, the mill was torn down, and, if I am rightly informed, a part of the machinery was taken out of the valley and the rest of it used in building the mills at Alamosa and La Jara. The mill at Hooper has only recently been dismantled as a flouring mill. As wheat growing was the biggest interest of this section, the milling industry may be assumed to present faithfully the course of the farming industry. Stock-raising, sheep, hogs and cattle, has enabled some to continue operations with some success, but as a general statement, the condition of this section of the valley has been deplorable for the past 10 or 15 years.

The towns of Mosca and Hooper are mentioned because they were the centers of this former prosperity, which was participated in by a large section of country.

The area now mostly unproductive is from 400,000 to 500,000 acres. The cause usually assigned for this condition is seepage.

SUB-IRRIGATION HAS CAUSED SEEPED LANDS

The system of irrigation used in the past was undoubtedly unfortunate and the practice of the people in applying it was in many cases unwise. I am credibly informed that, in some in-

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stances, in the application of sub-irrigation, the water-plane is raised to within 12 inches of the surface, while in the most conservative cases the aim is to raise it within 22 inches. It is not our intention to consider the conditions under which these results may be obtained or to discuss methods of irrigation, but simply to present the facts. One result has been the seeping of that section of the valley lying to the north of the Rio Grande and east of Center. This fact has called into existence the Gibson and Sylvester ditches for the purpose of drainage. The conviction is very general that drainage will remedy conditions in this section of the valley. It does not matter whether this conviction is wholly or only partially correct, it establishes the prevalence of this seeped condition.

SOIL IS NOT EXHAUSTED

Another cause of failure might be exhaustion of the soil. This probably plays only a small part, if any, in the present unfavorable condition of this section. How unfavorable this general condition is, is not appreciated by any except those who have an intimate knowledge of the country. The practice of the ranchmen in farming this land may have been bad, but exhaustion of the soil is not at all a contributing factor.

An ordinary agricultural analysis of a soil from Hooper gave the following results:

ANALYSIS OF SOIL, HOOPER, COLORADO

	Percent
Sand*	62.241
Soluble silica	15.229
Sulfuric acid	0.363
Phosphoric acid	0.320
Carbonic acid	2.629
Chlorin	0.081
Lime (calcic oxid)	4.295
Magnesia	1.595
Potash	1.383
Soda	1.326
Ferric oxid	3.930
Aluminic oxid	4.259
Manganic oxid (br.)	0.175
Ignition	2.260
Sum	100.085
Oxygen equal to chlorin	0.018
Total	100.067

* This sand consists of particles of igneous and other rocks rich in felspar and has, comparatively, a small amount of quartz particles.

This soil is quite typical of by far the larger part of the soils found in the valley and, so far as this kind of an analysis is reliable as an indication of the supply of plant food, the soil is excellent

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in regard to its content of phosphoric acid and potash. The nitrogen is not given in this analysis, but judging from the amount of this element found in other samples, it is probably about 0.10 of 1 percent. The question of exhaustion of this soil, even if we assume that the addition of nitrogen would be advisable, can be dismissed as the cause of the unproductiveness of this large section of the country.

"WHITE ALKALI" IS NOT INJURIOUS

Another cause often assigned for an unproductive condition of our lands is "white alkali". That there is alkali in this, as well as in other sections of the valley, is thoroughly well known. There is more evidence of this class of alkalis outside this section than within it.

It is natural that, when a section of country measured in square miles is covered by a white efflorescence, perhaps literally as white as snow, that it should make an impression upon one as an important factor in any unproductiveness of the land which may be observed. That this has been the case and has been passed on from one to another and from one section of country to another from the beginning of our agriculture till the present time is true, and it is unfortunate that it is true, for, whatever the results of laboratory experiments may be, I have yet to see the proof that these "white alkalis" constitute any seriously unfavorable factor in our field practice. When something is wrong, many of us, especially if we have not learned that it is no disgrace to acknowledge that we do not know everything, attempt to give a reason for the condition, whether it has anything to do with the question or not. In this way our ordinary "alkali" has been assigned as the cause of much evil.

I do not intend to go into this question here, but I may state that the alkali question is more complex than the average person imagines and includes much more than the white efflorescences so abundant, especially at times during the spring months, in some sections of the valley. This white efflorescence, our ordinary "white alkali", as it occurs west and south of Alamosa, or very generally throughout the valley, is essentially sodic sulfate, often mixed with calcic sulfate. I do not believe that these salts occur in these soils in sufficient quantities to cause any damage. The general reader should be reminded that these salts, as he sees them on the surface of the country, are what is left from the evaporation of large amounts of water which have brought them to the surface of the soil and left them there in the form of a very strikingly white powder whose quantity in the soil he greatly

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over-estimates. More especially has he been led to over-estimate the injurious effects of these salts. I remember the impression made upon me by the whiteness of the country west of Alamosa during a trip in the spring of 1914. For more than two miles the surface of the ground on both sides of the road was perfectly white and this condition extended, especially to the southward, as far as one could see. I measured this efflorescence at some points and found it attaining a thickness of one-quarter of an inch or rather more. I took a sample of this, analyzed it, and found it to contain more than 91.0 percent of sodic sulfate. It is not a matter that should cause surprise that such a condition should impress one as very bad indeed, but I do not believe that it is a fact that it is very bad.

Some years ago I took some samples of soils at La Jara. Among them there were two from a field planted to peas; the stand was irregular but the peas were thrifty. These two samples represented 6 inches of soil, the top 2 inches and the succeeding 4 inches. The top 2 inches carried 3.0 percent of salts soluble in water; the next 4 inches 1.5 percent. Of these salts, 65 and 46 percent respectively were sodic sulfate, the rest, essentially, calcic sulfate. The peas undoubtedly had pushed their roots to a greater depth than 6 inches, but they had passed through this 6 inches and they were thrifty. I have seen just as marked instances in the eastern part of Alamosa, where a good lawn and garden were separated from land heavily charged with this "white alkali" by an ordinary picket fence. In this case the effloresced alkali contained 96 percent of sodic sulfate. These are only a few instances of this character that I have met with which lead me to believe that ordinary, so-called white alkalis are of themselves not sufficiently injurious to justify their consideration in this connection.

"BLACK ALKALI" POISONOUS TO PLANTS

There is a so-called "black alkali", which consists essentially of sodic carbonate, whereas the "white alkali" consists essentially of sulfates. The "white alkali" does not discolor the land; the "black alkali", when the soil contains much organic matter, gives rise to very dark, almost black, solutions and crusts, for which reason it is called "black alkali". The alkali itself is not black, it is white, just as white as the so-called white alkali, but it dissolves organic matter (humus) with a brown or black color. This alkali is so corrosive that it will destroy the tissues of young plants and even of older ones, and, of course, may kill them. Another effect of sodic carbonate, "black alkali", is to make the ground puddle and cake so

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that when it is plowed it breaks up in hard cakes or lumps. This effect is so marked on some soils that the carbonate formed, due to the application of Chile saltpetre, cakes the ground so badly that anyone can tell just where the saltpetre was applied. This was so noticeable in a field in which I had made some fertilizer experiments that the plowman who was sent to do the fall plowing picked out of the 48 plots into which the field was divided, the 12 plots to which the Chile saltpetre had been added. The smallest amount added was 62.5 pounds to one million pounds of the soil. This would give rise to about 75 pounds of carbonate to each million pounds of soil, provided the largest possible amount of carbonate was formed, and yet this actually sufficed to puddle and cake the land to the extent that I have indicated. This amount expressed in percentage is seventy-five ten thousandths of 1 percent. This amount is very much less than is necessary to injure plants by directly eating off the roots or to poison them. The amount necessary to do this is from four to five one hundredths of 1 percent, or from 400 to 500 pounds in each million pounds of soil. This "black alkali" is really very poisonous to plants and its effect on the physical or mechanical condition of the soil is very bad.

NITRATES DESTRUCTIVE IF PRESENT IN SUFFICIENT QUANTITIES

There are still other salts that occur in our soils of which we must take some note, for they may easily become so abundant as to be injurious, or even to be fatal, to all vegetation. In bulletins Nos. 155, 160, 178, 183 and 186 of this Station I have described in some detail, the occurrence of these salts, nitrates, in some of our Colorado soils in such quantities as to kill vegetation, even old, well established apple trees. One of the very first occurrences of this sort that I recognized was in the San Luis Valley. The occurrence of these salts may have two effects. A small amount of them, 10 to 20 parts to a million parts of the soil, may produce big crops of oats or other farm products, whereas, too much of them will burn and kill the crop. At this time I wish only to call attention to the fact that this question exists in the agriculture of the San Luis Valley. I may state that I saw in Rio Grande County in the season of 1916, a quarter section that had been planted to peas, on which no peas were grown. The grasshoppers were blamed for the destruction of the crop, but no grasshoppers were to be found on the quarter section. Nitrates, however, were present in this soil in fatal quantities. These statements are made simply to impress upon the minds of interested parties that there

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are real, serious questions pertaining to the agriculture of the San Luis Valley besides the question of seepage.

There are still other salts whose occurrence is most remarkable, but they need not be so much as mentioned in this place.

HIGH WATER-PLANE NOT THE CAUSE OF CROP TROUBLES

The people of this valley themselves are not all satisfied that the benefits claimed for drainage have been realized or are attainable. That the presence of a high water-plane alone has, in fact, done the harm to the 400,000 or 500,000 acres of land included in the Moffat-Hooper-Mosca section is claimed by some. The view that I take is that this is not so. The water-plane is certainly too high in many places in this section, but in others, it is low enough for the production, under other conditions, of good crops, whereas this land produces nothing. In the practice of sub-irrigation, the water-plane is intentionally raised to within 22 inches, and even as near as 12 inches, of the surface, with no detrimental results; at least, this is the information that I have received. Doubting some of the information, I have made inquiry concerning the parties giving it, and concerning the facts; they seem to be reliable.

Agronomists may doubt that good crops of alfalfa may be grown year after year on land in which the water-plane is held within 12 inches of the surface throughout the growing season. It seemed to me remarkable but, after what I have seen and learned from some of these people, I feel compelled to accept their statements. I have presented these facts of farm practice because of their suggestiveness in connection with the claims made—that it is because of the waterlogged condition of the Hooper-Mosca section that it will not only not produce as in former years, but almost not at all. I have refrained from writing of these facts for ten years or more, but the bad condition of this section is now so well known to everyone that there is no good reason why one should not write frankly about it.

There is no question but that water has been used unwisely and that sub-irrigation is not the best practice for this valley, nor is there any question but that there should be drainage enough to take the water off the surface of the ground. There is, further, no question but that some bad results would be experienced in changing from the system of sub-irrigation to irrigating by furrows and flooding, but we have the following facts:

Good crops, even excellent crops, are raised by sub-irrigating, whereby a higher water-plane is maintained than exists in parts of the valley which are now practically wholly unproductive. If

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in the same country a high water-plane during the cropping season produces good results, why should we attribute the unproductiveness of other parts of the same country to a water-plane no higher, or to one that is even lower? So far as the variability in the height of this water-plane is concerned, there is not much room for movement, in the case stated, from 42 inches below the surface in the winter to 12 inches in the cropping season. The permanent water-plane in the unproductive section lies within these limits, at about 36 or 37 inches, according to my personal observations.

I do not think that any practical farmer will deny that the practical results obtained by the expenditure of considerable sums of money on drainage ditches have been disappointingly small. These experiments with drainage ditches have been made on a sufficient scale and length of time to justify a very good judgment of how much is to be hoped for from these alone and, as said, the results are disappointingly small.

ABUNDANT "WHITE ALKALI" OF VALLEY NOT A SERIOUS PROBLEM

Another fact is that the ordinary "white alkali" which occurs abundantly in the valley is not a serious problem, though it has been made to appear such. I am not alone in this view of the question and know that many practical men are fully convinced of this.

I shall not discuss the question of the occurrence of some chlorides in this valley at this time. The nitrate question is really of some importance and the occurrence of certain chlorides in this fresh water valley is an interesting problem, but they do not constitute the big important fact that I want to present in this bulletin.

"BLACK ALKALI" PRESENT IN DETRIMENTAL QUANTITIES

This fact is that, while the total amount of alkali in the soil of the Hooper-Mosca section is comparatively moderate, the character of this alkali is very bad. There is present, in most of the land, sodic carbonate, "black alkali", enough to be detrimental, if not fatal, to any crop that may be planted. The best information at my disposal indicates that the presence of 400 parts of sodic carbonate to the million parts of soil is injurious, or possibly fatal, while it is probable that few, if any, crops can survive in the presence of as much as 500 parts to the million. The amount of alkali in this land is generally taken at something like 1,000 to 1,200 parts to the million. This amount of "white alkali" would not be in the least dangerous, but if one-half of it were "black alkali", very serious trouble would ensue. In fact, the land would be ruined for all practical purposes.

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In order to ascertain how generally the carbonate of soda may be distributed throughout this district, I took two sets of samples, beginning in the first case a little south of McGinty and continuing to Hooper, and in the second case a little east of Center and continuing to Hooper, but to make the two series continuous, I shall give the results from Hooper to Center.

SODIC CARBONATE IN SOME SAN LUIS VALLEY SOILS IN PARTS PER MILLION

	Black Alkali in Parts Per Million
An old, gone-back ranch	865.0
Land in bad condition, crops failed	375.0
Land barren for some years	722.0
Land barren	925.0
Land barren, soil sandy	5103.0
Alfalfa field, stand good	144.0
Alfalfa field, stand medium, old	200.0
Alfalfa field, stand good	259.0
Sandy soil, alkali grass, some sweet clover	121.0
Diked and flooded soil	109.0
Sandy loam, uncultivated	253.0
Oats, a failure	609.0
Deserted land	200.0
Wholly unproductive land, treatment excellent	510.0
Wholly unproductive for many years	3222.0
Land just surfaced	200.0
Land flooded 1916 rye poor	398.0
Land flooded 1916, rye, only a little living	410.0
Land planted to peas; peas did not live	633.0

These samples represent flooded, cultivated and uncultivated lands and there is not one of them that does not contain notable quantities of this very objectionable salt. We see that flooded land planted to rye and containing 398 and 410 parts of "black alkali" to the million of the soil produced nothing. Further, that no single sample taken was free from this salt, even though some of it had just been flooded in the manner that is now frequently practiced in this section. The people, at least some of them, realize that this method, as practiced, is not a perfect success (see the two fields of rye), but they know that it is the best way yet adopted to handle this land.

If we can discover the source and supply of this carbonate, it will help us to form some clear notion of our chances of correcting the evil. It will help us to form an idea of how much we may hope to accomplish.

"Black Alkali" Comes from Waters of Valley

The source of this carbonate is the water of the valley. The artesian water at La Jara, obtained at 65 to 70 feet, is good water, and that obtained at Alamosa, at a depth of 923 feet, is also good water. This is not the case with the town well or the mill well at

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Mosca, nor with the mill well or the railroad well, or the town well at Hooper. These waters are brown, strongly alkaline and contain sulfur; they even smell of it. The older residents of the section well remember that there was a well near the present railroad station of McGinty that was called the soda well, because, so it was said, they could use this water instead of baking powder for making light bread. I never believed this story, but it shows that the water was remarkable and that the citizens were resourceful in presenting the advantages of the country. This well is now closed.

The presence of gas in this district is, in some instances, abundant enough to furnish light and fuel for the houses of the owners.

The conditions that cause the waters to be brown and to carry sodic carbonate in such easily recognizable quantities have produced the difficulties that threatened the district from the beginning and which the practice of sub-irrigation has made real.

All of the ground waters that I have examined from Center east to Hooper and from Hooper, I may add from Moffat, south to below McGinty, carry sodic carbonate in solution. In the case of the brown waters, there is present in the strata from which the waters come, enough humus which is soluble in sodic carbonate, to impart the brown color. Some of the wells near the edge of this area, especially shallow wells, carry sodic carbonate, though they are only slightly or not at all colored. The characteristic of our mountain waters is that they carry only a small amount of substances in solution, and these substances are silicic acid, the carbonate of lime, and the carbonate of soda. The silicic acid and the carbonate of lime can be removed easily, but not the carbonate of soda. This salt is not removed to any great extent when its solution passes through the soil, nor is it thrown out of solution by any agent or by the evaporation of its solution as the lime may be by the escape of carbonic acid on exposure to the air.

The artesian waters along and south of the Rio Grande are excellent waters for all domestic purposes; they carry carbonate of soda with the carbonate of lime and silica just as the waters of the mountain streams do and in only slightly greater quantities. This is not true of the brown waters, for they carry almost nothing besides the sodic carbonate and they carry a great deal of this salt. The mill well at Mosca, for instance, carries 1½ pounds of sodic carbonate in every 1,000 pounds of water and only 1-10 of a pound of all other solids taken together. A barrel of this water weighs a trifle over 300 pounds and this well will furnish a great many barrels in an hour.

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A few results stated in parts to the million will serve to show how generally and abundantly this salt occurs in these brown artesian waters.

SODIC CARBONATE IN SOME ARTESIAN WATERS

	Parts Per Million
Rio Grande water	14.1
Bucher Well, 923 feet deep Alamosa	68.0
Well near McGinty, shallow	371.0
Well north of McGinty, deep	1229.0
Well at Mosca, shallow, 1st flow	318.0
Well at Mosca, 780 feet deep	1388.0
Well between Hooper and Center, 375 feet deep	79.2
Well between Hooper and Center, 739 feet deep	477.0
Well at Hooper, 1st flow	371.0
Well at Hooper, 780 feet deep	1446.9
Well near McGinty, 15 feet deep	236.0
Sylvester drainage ditch	228.0

The water of the Gibson drainage ditch is not rich in total solids and carries but little sodic carbonate. Alkali from a claim, Harper I think was the claimant's name, was rich in sodic carbonate, as was also an incrustation taken from near the ditch.

These data are enough to show how rich these brown waters and all others in this section are in sodic carbonate compared with the Rio Grande water or with the deep artesian water at Alamosa.

Brown Water Kills Vegetation Because It Contains "Black Alkali"

These results show that even the drain-water and that of shallow wells is rich in sodic carbonate. This sodic carbonate does not make the water unpleasant to drink, on the contrary, waters carrying only a moderate amount of it are pleasant waters; for instance, the waters from the first flow at either Mosca or Hooper which carry less than 400 parts per million are agreeable, though they taste slightly of sulfur. The water from the 15-foot well near McGinty is very pleasant to drink, though it carries 236 parts of sodic carbonate to the million. It is a very different matter when these waters are applied to the surface of the ground or to crops and allowed to evaporate to dryness or the solution to become concentrated. When this happens, the crops will not grow and the land becomes hard and difficult to handle. Such land does not necessarily show any other signs of its bad condition. This is the explanation for the fact that this brown water is not good for irrigating purposes. This is the reason for its killing vegetation.

I saw a meadow north of Blanca, and about east of McGinty, to which some of this brown water had been applied. The vegetation had been killed, whether it was blue-stem or sedges. The

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water was not good for it. This explains, too, the statements made to me by a party who had taken up a desert claim, that, "the more water I used, the worse I was off". He claimed to have raised good crops the first year or so, but that subsequently he could raise nothing. I gathered two samples of alkali at this man's place and found that one of them carried 40 percent and the other 15 percent of sodic carbonate, or "black alkali". This man had come to the conclusion that he could raise nothing on this land. He hoped only to use it for grazing purposes. His judgment was good, for it was based on experience; he had tried to grow grain and alfalfa and they would not grow. The land contained enough sodic carbonate to kill these plants. Some of the artesian water that he obtained on this place was good for domestic purposes.

The presence of sodic carbonate explains the experience of another man who stated that water flowing from a well had spread out over a strip of ground and continued to do so for several months, and after this nothing would grow on this land. This took place several years ago and the land has not yet recovered.

The brown artesian water is bad and the testimony of users of water in the valley is that they prefer river-water to artesian for irrigating their crops. The brown artesian waters have not been used for irrigating but they, as well as the water from the shallow well and that from the drainage ditch, show that this "black alkali" is in the soil and, more than this, that it is in all of this section of the valley down to a depth of 780 feet at least. The greater the depth from which the water comes the richer it is in "black alkali". (See preceding analyses.)

SUB-IRRIGATION, EVEN WITH RIVER-WATER, BRINGS "BLACK ALKALI" TO THE SURFACE BY CAPILLARITY AND EVAPORATION

The system of irrigation generally practiced is sub-irrigation, in which the water-plane is brought within a few inches of the surface, from 22 to 12 inches. River-water is used for this purpose but it effects the bringing of this "black alkali" to the surface by capillarity and evaporation. The fact that it is possible to maintain the level of the water so near the surface shows that for some reason or other the water does not run down through the soil to any great depth, but is held near the surface, either because the lower part of the soil is so full of water that the irrigating water applied simply lies on top of the previous water-table, or that the lower portion of the soil won't let the water run through. The fact is that, in this portion of the valley, the water-plane is generally high; I found it 36 or 37 inches below the surface, but it can be

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found at a less depth in other places. This ground-water carries about 260 parts of "black alkali" to the million parts of water. It mixes with the river-water added in sub-irrigating the land and brings the "black alkali" with it. This went on for a number of years till the land became so rich in "black alkali" that crops were no longer successfully raised and this is the condition today throughout this section of some 400,000 or 500,000 acres. Most of the people of the valley still think that sub-irrigation is a good system. A few are convinced that it is not.

CONDITIONS CAN BE CORRECTED

The important questions for the valley are, Can this condition be corrected? and, Is it feasible to correct it?

I answer "Yes" to both questions, but there are difficulties in the way.

The conditions are very bad. There is no hope of removing, in any way, the great reserve supply of sodic carbonate as indicated by the richness of the artesian waters in this "black alkali". This section of the valley is full of this water, and the deeper we go the richer is the water in "black alkali". The more of this water we bring to the surface or allow to leak into the upper strata out of uncased wells, the worse we are off. No man can tell how long it has taken to bring about these conditions, but they have already existed from the very early history of the valley and, so far as we are concerned, they are as permanent as the mountains inclosing the valley. The water has probably never run out of this section of the valley and the deep artesian waters never will, if we measure time in terms of human lives.

We do not care how these conditions have come into existence, the question is, To what extent can we modify them? Can we modify the surface portion of this land so that we can raise crops?

GYPSUM WILL CONVERT "BLACK ALKALI" INTO HARMLESS "WHITE ALKALI"

It is well known that gypsum, sulfate of lime, will convert this "black alkali" into "white alkali", which is so good as harmless compared with the black. By the application of this gypsum we can mitigate the evil, but this will be a difficult problem if we continue the practice of sub-irrigation which brings the "black alkali" up; it will be necessary to change the system and wash the "black alkali" with the gypsum down. The people have found out that, at the present time, about the only thing they can do to make any headway against the present conditions is to dike and flood the land. There is usually space enough between the permanent water-plane and the surface to permit them to better the

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conditions in this way by carrying the "black alkali" into the deeper portions of the land, but they do not destroy it or even permanently remove it. The addition of a sufficient amount of gypsum, theoretically, 1¾ pounds for every pound of "black alkali" in the soil, practically about 9 pounds of gypsum to one of "black alkali", will change it into "white alkali" and then the land will not get hard for 4 inches on the surface and the crops will grow again. The application of the water must be to the surface by means of furrows or by flooding.

A very important consideration is, How can the gypsum be obtained? It would have to be brought in, as this mineral does not occur in the valley. At the present time, freight rates are prohibitive. The net cost to me of 6 tons of ground gypsum at Portland was $24.00, the freight to Center was $48.00. The cost of this gypsum was too high and the freight was much worse.

While gypsum does not occur in the valley, it is usually very abundant between the first line of hogbacks, the Dakota sandstones, and the east flank of the Front Range. It usually outcrops and its quarrying is easy. The quarrying, transportation and grinding ought to be a community matter if this section of the valley is to be reclaimed. These things must be done on small profits.

Some drainage is necessary to reclaim portions of this land, but how much benefit is to be expected from large systems, aiming to drain the whole section is an open question.

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HARVESTING AND STORING VEGETABLES FOR HOME USE

BY
J. J. GARDNER

Series of Compartment Pits

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HARVESTING AND STORING VEGETABLES FOR HOME USE

By J. J. GARDNER

The home garden should be planted with a view to furnishing a large assortment and a continuous supply of vegetables, not only during the growing season, but for winter use as well. Most people have no conception of the number of common vegetables that may be kept in a fresh or preserved state for winter use. The list includes about 30 different kinds. There are about 20 different kinds, namely, potatoes, beets, carrots, horseradish, winter radishes, parsnips, rutabagas, salsify, turnips, kohl-rabi, cabbage, celery, leek, chicory, parsley, onions, dry beans, pumpkins, squashes and sweet potatoes that may be easily stored in the fresh state.

In addition, the following vegetables may be had for winter use by either canning or preserving: Rhubarb, tomatoes, sweet corn, peas, string beans, cauliflower, cucumbers, citron, green peppers and green tomatoes.

TIME OF PLANTING

In order to secure the best results in storage, it is generally necessary to regulate the time of planting so that crops will be at the proper stage of maturity at the right time for storage. For example, beets sown extremely early in the spring would hardly make desirable roots for winter storage because of their being over-grown and woody. Later planting would produce smaller beets of better quality for winter keeping. No particular care is necessary in regard to the time of planting for vegetables which are to be canned or preserved, except that they be given plenty of time to develop and that there be a sufficient quantity available at the right time.

HARVESTING

The time for harvesting, where crops are to be stored, is just as late in the fall as possible, avoiding any possible chance of injury by freezing. This time will vary slightly with different vegetables; for instance, turnips may be allowed to remain in the ground longer than beets, they being more hardy, and beets slightly longer than carrots. Only vegetables free from blemishes or injuries should be used.

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Vegetables to be stored for winter use should be harvested and handled with care. Root crops, such as beets, carrots, winter radishes, rutabagas, turnips and kohl-rabi may usually be harvested by pulling by the tops. In case the vegetables are long rooted, digging with a fork may be necessary.

Horseradish, parsnips, salsify and chicory usually require digging in order to get the root out without injury, and should be removed so that the tip is not more than a quarter of an inch in diameter in case it is broken off.

Cabbage, celery and parsley are taken roots and all with the soil clinging to them. Only injured parts are removed. Root tops should be removed carefully, cutting about three-fourths of an inch from the crown of the vegetable so that no injury will occur. Otherwise, the roots are subject to bleeding and soon wither because of loss of moisture. The portion of the leaf remaining on the crown soon withers and falls off, with no injury to the root.

Onions for winter storage are harvested when the necks begin to wither. The tops are removed and the onions placed in a well ventilated place, preferably under cover, to "cure".

STORAGE

Nearly all of the common vegetables are satisfactorily stored under one of four conditions:

1st. Cool, moist conditions and no circulation of air.

2nd. Cool, dry conditions with a circulation of air.

3rd. Cool, moist condition of roots and a circulation of air about the top.

4th. Warm, dry conditions with a free circulation of air.

Most of the common vegetables are stored under the first condition of coolness, moisture, and no circulation of air, namely, potatoes, beets, carrots, horseradish, parsnips, winter radishes, rutabagas, salsify, cabbage and kohl-rabi.

The second group includes only the onion.

The third group includes such vegetables as the celery, leek, brussels sprouts, chicory and parsley that continue their growth in storage.

The fourth group includes such vegetables as dry beans, sweet potatoes, pumpkins and squashes.

The conditions for the first group may be met in several ways. Where only a limited supply is to be stored, the best method is to

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place the vegetables in a box of moist sand or soil in layers. Where larger quantities are to be put away, they may be stored in what is known as an out-of-door pit.

Parsnips, salsify and horseradish, being perfectly hardy, are not injured by freezing and may be left in the ground over winter, but it is often difficult to secure them when wanted, under these conditions. They may be placed in a conical pile in a well drained place and covered with about six inches of earth which may be chopped away at any time it is desired to get at the vegetables.

Beets, carrots, winter radishes, rutabagas, turnips and kohlrabi are not hardy and must be protected from freezing. The vegetables are placed in a conical pile on a well-drained piece of land, covered with a layer of from six to eight inches of straw, and about the same amount of earth, leaving some of the straw protruding at the top to provide ventilation, as the vegetables are likely to develop some heat when first covered. As soon as cold weather sets in, the earth may be thrown over the top to completely seal the pit. In extremely cold sections, a layer of strawy manure is sometimes put on the top of this after the earth covering has become frozen.

Pit of Beets opened April 15th

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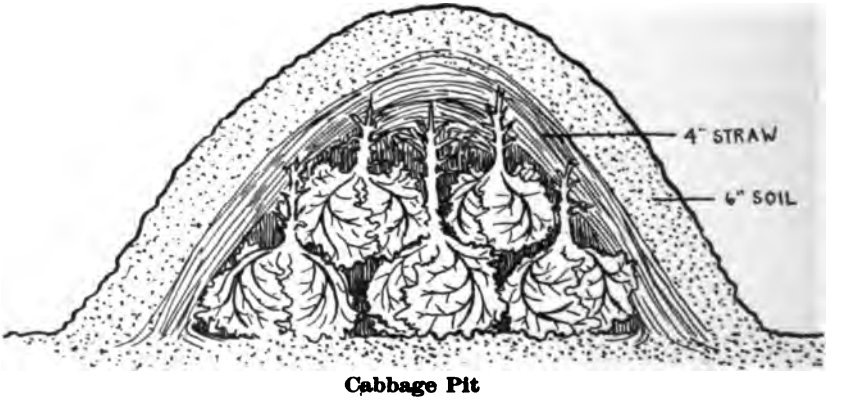
Where a considerable quantity of vegetables is to be stored in this way, a series of pits, one adjoining the other, may be made, with only an amount of vegetables in each pit that can be economically used at any time. In this way, no pits are opened until the vegetables are to be used.

Cabbages are stored by placing them head down three in a row and two on top making a tier of five cabbages, the roots extending in the air. The pile may be as long as necessary. Several inches of straw or leaves should then be put over the cabbage and the same amount of earth thrown on them. Cabbage may be kept frozen solid without injury to the head, providing it is thawed out very gradually.



Cabbage Pit

Onions, in limited amounts, may be easily stored in a cool place where there is a free circulation of dry air about them; the main point to bear in mind is that they require a low temperature, as they sprout readily where there is any heat. A bushel or so may be hung up in a basket suspended from a rafter in a cool cellar. Larger quantities are usually stored in slatted crates, one piled on top of the other, allowing a free circulation of air between the crates.

Celery, leek, brussels sprouts, chicory, and parsley—vegetables that continue their growth after storage—are transplanted with soil clinging about the roots.

For home purposes, parsley may be taken and put into a pot or box and kept well watered, at an ordinary room temperature.

Celery, leek and chicory, in a small way, may be transplanted into a box, with holes in it for ventilation, and the roots covered with moist sand or soil, the air being allowed to circulate thru the

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tops. Watering will be frequently necessary and should be applied to the roots and not the tops; otherwise disease is liable tc start, and decay soon follows.

Brussels sprouts require more room than the celery and it is hardly practical to store them in a box, but they may be put upon the floor of the cellar, the roots covered with moist sand or soil and kept in this way.

Celery, leek and chicory may be also placed under the same conditions, or, if a hotbed is available, they may be transplanted into the bottom of the bed and kept for a considerable length of time, if additional covering is put on during severe weather.

Dry beans, sweet potatoes, squashes and pumpkins, in a limited way, may be stored on a shelf in a furnace-room, or in a warm place, where they may be kept dry and free from moisture. In order to insure squashes and pumpkins keeping satisfactorily, they should be harvested with the whole stem and part of the vine attached—otherwise, they are likely to start decaying on the stem end.

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Bulletin 233 June, 1917

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

GRASSHOPPER CONTROL

By

CHARLES R. JONES

A field demonstration of mixing and application of Paris green-bran mash, conducted on the premises of Mr. Tiner, grasshopper campaign, 1916, San Luis Valley (Original).

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GRASSHOPPER CONTROL

By CHARLES R. JONES

The agricultural interests of the United States have suffered for many years from the depredations of locusts, or grasshoppers, and every farmer should be more familiar with the methods of control. Usually the question of grasshopper control becomes a problem for concerted action, but co-operation is not always possible and the individual farmer should at all times keep this problem before him for consideration. In almost every county of Colorado there have been outbreaks of this pest, and various remedial measures have been applied. Should weather conditions favor insect development this year, practical control methods should be used to save the crops.

The past season witnessed several outbreaks in various parts of our State which were successfully controlled, and there is no longer any reason why the farmers should allow their crops to be destroyed by this pest. They are better informed than ever before as to the life history and habits of the grasshopper and the most efficient methods of destroying them. Colorado's "Amended Pest Law" provides for the forming of pest districts for the control of rodents and injurious insects, and can be applied effectively in all localities. This measure should have the active support of all county commissioners to give a basis for a county-wide organization, and the direct application of remedial measures for the complete control of this invading pest.

The general life history, habits, and practical methods of control of grasshoppers have been worked out and are given here, in order that the farmers may intelligently and successfully combat the pests. The investigations upon which this paper is based gives information that can be applied in any part of the State.

LIFE HISTORY

Egg.—The life histories of our various species of destructive grasshoppers are very similar. The female usually selects a spot to oviposit in some waste land. Ideal places are found along fence borders, ditch-banks, roadsides, weedy patches or fallow lands. Cultivated fields are not so susceptible to oviposition as the above mentioned places. The individual spot selected is generally slightly elevated, dry and somewhat protected from the sun.

After selecting a suitable place, the female forms a hole by forcing the tip of her abdomen down into the soil, and alternately

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opening and closing the four horny processes at its tip. The depth of the hole depends upon the texture of the soil and the length of the abdomen of the hopper in question, the eggs being deposited between one-half and one and one-half inches from the surface. Upon completing this operation, the female deposits her eggs (Plate 1, Fig. 1), beginning at the bottom and gradually laying them singly and obliquely across the hole, at the same time covering the entire mass with a frothy mucilaginous substance which is secreted from the abdomen and forms a protective covering against dryness, excessive moisture, and, possibly, parasites.

All our injurious grasshoppers pass the winter in the egg stage. Active oviposition commences about the middle of August and extends thru the remaining warm days of fall, at least to the middle of November. Hatching begins in the following spring with the advent of the warm days of May and early June, and continues over an extended period, there being a great variation in time of hatching, as in oviposition.

The number of eggs laid varies with the species, generally ranging from 40 to 120. There are usually two egg-clusters deposited by the same female.

The individual eggs are cylindrical, about three- to four-sixteenths of an inch in length, curved slightly, and of a yellowish color. (Plate 1, Fig 2.)

Nymphs.—Upon hatching, the young hoppers, or nymphs, readily force their way to the surface of the soil thru the protective covering of the egg mass. The young hoppers closely resemble the adult, except that they are wingless and the head is very large and out of proportion with the rest of the body. They are very pale in color at first, but soon take on the coloration of their surroundings which, together with their small size, makes them very inconspicuous.

After hatching, the nymphs remain grouped for a day or two, but they soon develop ravenous appetites and begin feeding upon any green herbage. They do not feed at night, but usually crawl upon some grass stem or other object, where they remain until it begins to warm up the following day.

During the process of development, the nymphs molt a series of times, each successive skin being larger than the preceding one, and it is in this manner that the insect grows. When ready to molt, the hopper ceases feeding, crawls on some grass stem or other object, and fastens itself thereto by its hind claws, head downward. Thus it hangs motionless for several hours. The thorax or middle part of the body gradually swells until the skin splits down the

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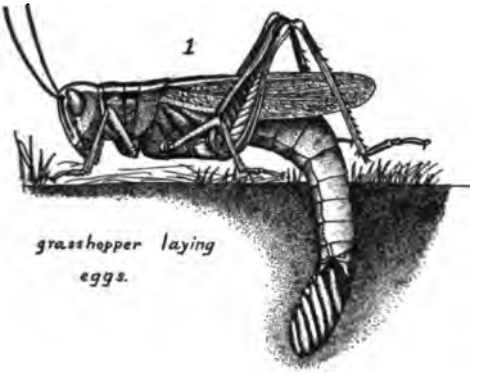

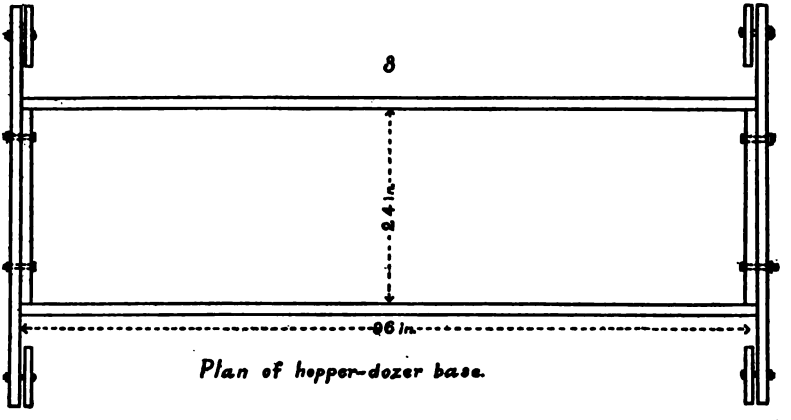

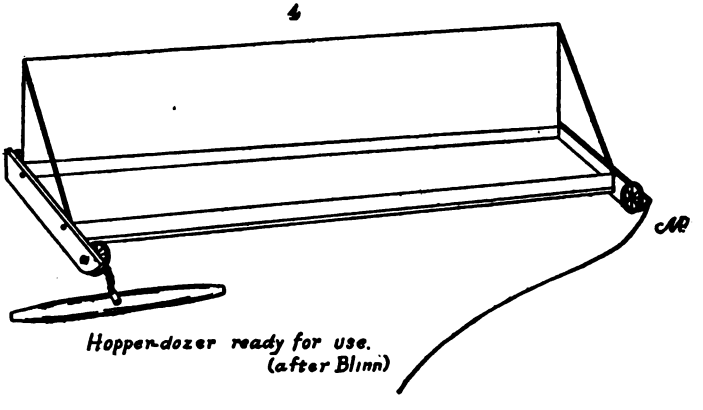

Plate I

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back. Then by a series of muscular contractions, the body of the insect is gradually worked out of the old skin. The nymph usually clings to the old skin for a short time until the tender new skin becomes dry and sufficiently hardened for it to be able to move about.

The time required for the nymph to reach maturity, that is, to gain its wings, is from 60 to 90 days, depending upon the climate and locality. During this period, there are generally five molts.

While this pest is in the nymphal stage, the farmer should endeavor to eradicate or control it, as its only means of locomotion is by hopping, and the methods and application of remedial measures require less labor and materials, as the insects cannot escape by flying to uninfested or untreated areas, as they will do when maturity is reached.

Adults.—At the fifth molt, the wings of the hopper, which have been mere pads, become fully formed. When ready to transform from the nymph to the adult stage, the young hopper climbs to some upright object and remains, as in the preceding molts, motionless until the old skin is shed. The wings, which have been represented in previous molts by mere pads, now come into evidence, and after they are thoroly dried, which is usually before nightfall, the hopper is ready to fly.

Climatic conditions affect the adults in the same manner as the nymphs. They are very active during the warm, sunny days, and are sluggish and quiet during cold, wet weather.

Egg Laying.—After the adult stage has been reached, which varies considerably, owing to variation in egg laying, oviposition and rate of development in individuals of the same brood, the females feed for a week of two, during which time they develop a mass of eggs and then oviposition takes place. The places selected will extend over a considerable area of ground in such places as before mentioned.

FOOD HABITS—PLANTS AFFECTED

Unlike most other insect pests which attack plants of an economic value, the grasshoppers are able to exist upon almost any green herbage, in most cases attacking the tender, succulent growth of the plant in question. In our irrigated sections, young alfalfa affords an ideal food for them, as well as young small grains, corn, field peas, and any garden or truck crop. Deciduous trees do not escape the ravages of this pest. Orchard trees, roses in the flower gardens, and even willows along ditch banks suffer severely at times. Young fruit trees are often severely injured by defoliation, or even by having the tender bark and twigs eaten to such an ex-

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tent as to cause death of the trees. The attacks and damage to young orchards generally follow a shortage of other foods.

THE MORE DESTRUCTIVE SPECIES

There are many kinds of grasshoppers which are injurious to our agricultural crops. The more important ones are: The lesser migratory locusts (*Melanoplus atl. nis* Riley), the two-striped locust (*Melanoplus bivitatus* Say), the differential locusts (*Melanoplus differentialis* Thom.), and the red-legged locust (*Melanoplus femur-rubrum* De G.).

There are other species involved, but they appear rather scattering, are of minor importance, and generally occur in fields bordering virgin lands.

CONTROL

The control of grasshoppers may be taken up under two heads:

First, ***Natural,*** which includes climatic conditions, predaceous and parasitic insects, diseases, birds, etc.

Second, ***Artificial,*** which includes all methods employed by man, such as cultivation, spraying, poison baits, hopper dozers, etc.

The complete eradication of a swarm of locusts in any given locality is almost impossible, tho under favorable circumstances, with co-operation and organization, enough can be killed to effect a complete control of the pest. However, this must be accomplished before the hoppers develop wings. Therefore, the attention of those engaged in locust destruction should be directed against the young hoppers and eggs.

NATURAL CONTROL

Insect Enemies.—There are several kinds of parasitic and predaceous insects which aid materially in the natural control of grasshoppers. Among these is a medium-sized fly, *Sarcophaga* (sp. ?), which has been bred in abundance from both nymphs and adults. This parasite was first noted at Trinidad June 1, 1916, and after haying, numerous parasitized hoppers were noted around the stacks. From two to four parasites of the above mentioned species were bred from those collected.

Other insects of secondary importance have been noted preying upon the nymphs of grasshoppers. A large, black ground beetle, (*Calosoma obsoletum* Say) was noted, on various occasions, feeding upon young hoppers. Large robber flies (*Promachus* sp.) have been seen feeding upon young grasshoppers. Solitary wasps are also instrumental in hopper control. They sting and stupefy the young hoppers and place them in their mud nests. The wasp deposits an egg among the stupefied hoppers, and, upon hatching,

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the young grub has sufficient food for its development. One of the most common of these is *Prionony n atratus.*

Birds.—Insectiverous birds play a most important part in natural control of grasshoppers. They are always present thruout our agricultural districts, and are constantly feeding upon grasshoppers and other insects. The following are pointed out by W. R. Walton* as being the most important:

"Franklin's gull, bobwhite, prairie chickens, red-tailed, red-shouldered, broad-winged and sparrow hawks; the screech and burrowing owls, yellow-billed cuckoo, road-runner, nighthawk, red-headed woodpecker, kingbird, horned lark, crow, magpie, red-winged and crow blackbirds, meadowlark, lark bunting, grasshopper and lark sparrows, butcherbird, wren and robin."

All domestic fowls will feed upon grasshoppers whenever possible. Turkeys and chickens will aid materially in controlling them. They are very effective over small areas, as they will eat a great quantity of young hoppers. However, their effectiveness must not be over-estimated, as it is almost impossible for any farmer to have a sufficient flock to patrol his entire field. The wandering habit of turkeys takes them thruout the infested areas where they are very beneficial in hopper control, but chickens are of a different nature, and their houses must be placed in the infested field and be moved at intervals, if they are to rid a given locality of this pest. Mr. Jones, of Monte Vista, placed a coop and about 60 chickens (Fig. 1) in his field and affected a com-

Fig. 1.—Chickens in the field used as a method of control for grasshoppers, 1916, San Luis Valley. They did very efficient work immediately around the portable coop, which was moved every other day (Original).

*"Grasshopper Control in Relation to Cereal and Forage Crops," Farmers Bulletin No. 747, U. S. D. A. (1916), p. 12.

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plete control immediately surrounding the house. It must be taken into consideration that it would require an enormous number of hens and considerable attention to affect control over any great area of land.

ARTIFICIAL CONTROL

In the artificial control of grasshoppers, we may consider the two main heads: ***Prevention*** and ***Remedies.***

Under the first, attention must be given to prevent hatching and lessen egg deposition. The latter may be brot about by clean cultivation along ditch banks and fence rows. This will expose the hoppers to natural enemies and weather conditions, which will reduce their numbers and cause the remainder to oviposit in areas likely to be cultivated, and so result in a subsequent destruction of the eggs.

Exposure of the eggs to air, sunshine, natural enemies and weather conditions is very effective in hopper control. This may be accomplished by plowing, discing or harrowing. The operation should be performed before the eggs hatch. It is therefore an excellent plan, in late fall or early spring, to plow all ditch banks, fence rows, and road-sides where grasshopper eggs are known to be deposited. Plowing should be at least eight inches deep. This will bury the eggs sufficiently to prohibit most of the young hoppers from making an exit thru the soil surface upon hatching. In alfalfa fields and other places that cannot be plowed,

Breaking fallow land to destroy grasshopper eggs, San Luis Valley, 1916. (Original).

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harrowing or discing will give excellent results in egg destruction. This should be to a depth of at least two inches, the ground thoroly stirred, and the egg clusters broken and exposed. This allows birds and other enemies, as well as temperature, to destroy them.

Young orchards may be protected by thoroly spraying the trees with arsenate of lead at the rate of 3 pounds of powder or 6 pounds of paste, to 50 gallons of water.

APPARATUS FOR CAPTURING GRASSHOPPERS

There are three principal mechanical devices used in catching young grasshoppers. These are all under the same general plan, but may be classed as the "Hopper Dozer", the "Balloon Hopper Catcher", and the "Live-Hopper Machine". The first two are designed to be used on level cultivated fields or meadows, and are the most economical methods for mechanically destroying grasshoppers, but their use will not insure as complete and effective control as the poison bait method. However, some users of the above machines are very much in favor of them. This is probably due to the fact that with these they can see the immediate fruits of their labor.

Hopper Dozer.—A very cheap and practical hopper dozer (Plate 1, Figs. 3-4) consists of a sheet-iron pan three or four inches deep, placed upon wooden runners with an upright oil-cloth or piece of canvas two and one-half feet high at the back. This is to prevent the insects from flying or jumping over the pan. When ready for use, put an inch of water in the pan with a little coal oil and drag it across the field, and the hoppers will jump or fly into it. The horses should be hitched, well spread, at either end of the dozer, so as not to frighten the hoppers from in front of it, and then, as the machine approaches, many of the hoppers will jump and alight in the oil and water. The winged hoppers will, in most cases, fly against the back of the hopper dozer and fall into the pan and be killed by the oil. Those that crawl out will soon die from the effects of the oil. Where the hoppers are very numerous, they will soon fill the pan and have to be removed. At intervals, a fresh supply of oil and water will be needed. To prevent slopping from end to end, it is well to put partitions across the pan every two or three feet with a small opening beneath them.

Anyone can build one of these pans or dozers to suit himself. Mr. P. K. Blinn*, of Rocky Ford, Colorado, has constructed a

*"A Hopper Dozer," Bulletin No. 112, Colorado Agricultural Experiment Station.

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very inexpensive and convenient hopper dozer (Plate I, Figs. 3 and 4), which may be operated with one horse. The plan is such that any farmer should be able to construct it for himself.

The pan was made by nailing a sheet of 24-gage galvanized roofing iron, 30x96 inches, to a frame, 24x96 inches, made of two-by-fours. Three inches were allowed to turn up on either side of the frame to make the pan more secure. A strip of candle wicking was nailed beneath the iron between two rows of nails, to prevent leakage. The ends of the pan were bolted to runners made of 2 inch x 10 inch strips, 4 feet long, and at either end of this runner was a small cast iron 10-inch wheel. The object of the wheel was to steady the pan over rough places and to lighten the draft of the dozer. The pan was supported on runners about four inches above the ground and the wheels supported the runners about half an inch. A light frame, 3 feet high, covered with oilcloth, was fitted to the back of the dozer with the smooth side in front. The bottom of the cloth was tacked to the inside of the pan, and the framework was braced in front of the runner.

The material and cost of building the dozer, according to Mr. Blinn, was as follows:

One sheet of No. 24 galvanized iron. 23 lbs., 92	$2.07
One piece of 2x4, 16 ft.	
One piece of 2x4, 8 ft.	
One piece of 2x10, 8 ft.	
One piece of 1x4, 16 ft.	
Total—32 ft. at 2½c	.95
Three yards of table oilcloth at 18c	.54
Four cast wheels	.50
Bolts, nails and rope	.40
One ball of candle wicking	.10
Total cost	$4.56

By hitching a horse in front to one runner, and having a rope from the other runner attached to the hame staple of the harness, the dozer, by the aid of the wheels, may be dragged at right angles and to one side of the horse, thus preventing the hoppers from being frightened away from the advancing pan.

Balloon Catcher.—The "balloon" hopper catcher consists of a light frame of wood twelve feet long and two feet high, to which is attached a bag about eight feet long, the framework forming the mouth of the bag. The apex is open, but, when in use, tied with a string. The apparatus is drawn by a single rope which forks and re-forks, sending a branch to each corner. The draw rope is fastened to the single-tree of a light harness or to the pommel of a saddle. In dragging this sack over the infested areas

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A hopper dozer in action. One of the many machines that was used in the grasshopper campaign, 1916, San Luis Valley. Note the hoppers in the pan. (Original).

the hoppers jump to avoid it and are caught in the sack. When a sufficient quantity of hoppers are thus trapped, the rider, with the assistance of a helper, opens the apex and shakes the captured grasshoppers into a sack.

This apparatus originated in British Guiana, and is used extensively in India and other countries where grasshoppers appear in immense swarms.* It was also used effectively in Utah in the outbreak of grasshoppers in 1915, when it was reported that at least four hundred tons of grasshoppers were captured by the use of these balloons.**

The Live Hopper Machine.—This apparatus (Plate II) was constructed and successfully used in Colorado in 1902, and has later given satisfaction as a hopper machine in Utah and New Mexico, and in the San Luis Valley the past season. It has the advantage over other hopper dozers in that it can be operated on rough areas. Its construction is very simple. It consists of a rectangular box two feet square and sixteen feet long, fastened on runners. The top and back of the box should be covered with screen wire and provided with a door for getting the hoppers out. The front should be concave, three feet high, and covered with

*Philippine Agricultural Review III, 4, 1910, pp. 237-238.

**"How to Control Grasshoppers," Utah Agr. Exp. Sta. Bul. No. 138, 1915, pp. 98.-99.

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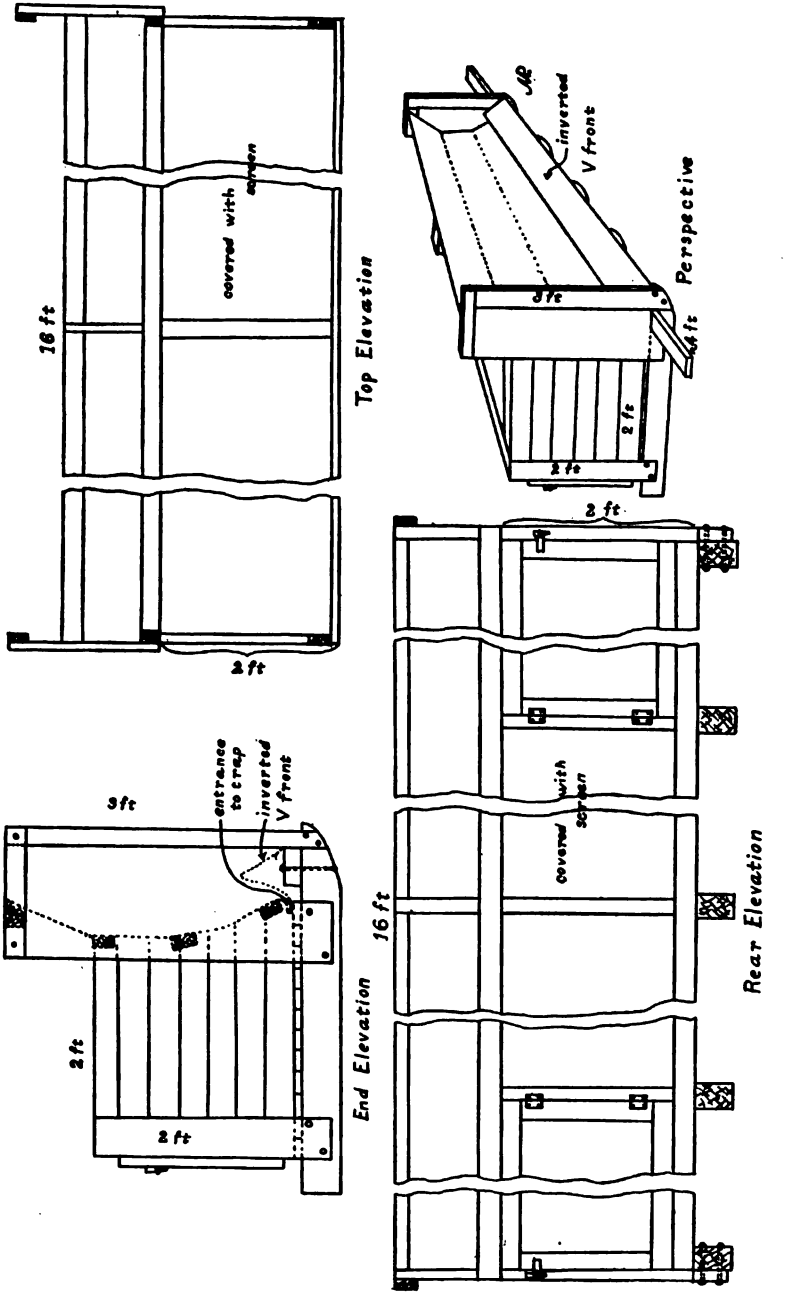

Plate II

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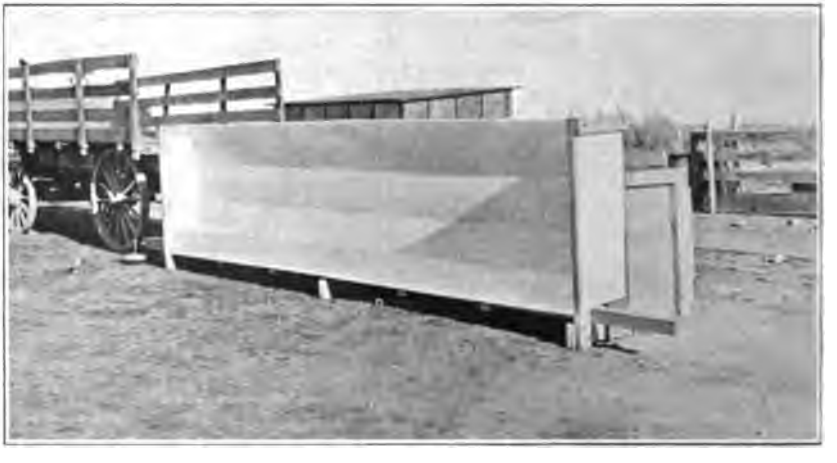
oilcloth or tin extending to within two inches of the bottom of the machine, the floor of which is extended forward about four inches in front of the shield. A two-by-four extends outward from either end to the distance of four feet and to this is attached the single-tree. An inverted V-shaped tin is fastened to the front end of the extended floor, the back part of the V being free and slightly curved upward and extending under the base of the shield. In operation, this tin shakes up and down, and the hoppers jumping up strike the curved shield, slide down to the inverted V front, and, being unable to obtain a foothold, pass down and under the main shield and into the box.

This machine operates in the same manner as the hopper dozer, with the exception that the hoppers must be killed before the machine is unloaded. This may easily be accomplished by spraying them with kerosene.



The "Live Hopper Machine," showing concave shield front and inverted "V" at the base. These machines were used on rough areas in the grasshopper campaign, 1916, San Luis Valley. (Original).

INSECTICIDES

Insecticides used in hopper control may be grouped under two heads, those which kill by contact, such as kerosene, kerosene emulsion, etc., and those which act upon the digestive tract. The latter may be applied by means of spraying the poison directly upon the foliage which the hoppers will feed upon, or by mixing it with bran or other material in the form of a mash.

Poisonous Sprays.—Poisoning vegetation with arsenical sprays is often practical in areas where the young hoppers are

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abundant and localized about the borders of the fields or elsewhere. The poisons used should be Paris green or arsenate of lead, the former at the rate of 2 pounds, and the latter at about 3 pounds of powder or 6 pounds of paste, to 50 gallons of water. Care should be taken not to use these sprays on plants where domestic animals are likely to feed. Either of the above sprays can be used very effectively after cutting alfalfa. In these cases, narrow swaths of alfalfa should be left standing at intervals thruout the field and thoroly sprayed with one of the above poisons. This green strip will act as a trap row and innumerable hoppers will be killed. After the hoppers are all killed, this trap-strip should be cut and burned, to eliminate the danger of feeding to domestic animals.

There is one objection to the use of the spray method, and that is that it is rather hard to make the spray material adhere and spread on plants sprayed. This, however, can be partly overcome by adding about 3 pounds of common laundry soap to 100 gallons of the spray.

Arsenic-bran Mash.—This can be used effectively, and it is one of the very best methods for controlling a grasshopper plague. Mix thoroly, 25 pounds of bran with 1 pound of white arsenic or Paris green, and enough water to moisten it so that the mixture will adhere. About 3 gallons of water will be sufficient. Add 2 quarts of some common cheap syrup to keep the bran from drying out too readily and make it more attractive to the hoppers.

The above quanity of materials, properly strewn, is sufficient to sow around 5 or 6 acres and will completely cover 3 acres. This would cost about 30 cents per acre, figuring the cost of materials as they were the past season.

The poison should be sown broadcast where the hoppers are the most abundant. Avoid dropping it in piles, as more hoppers are reached and better results are obtained where the particles are as small as possible. This mixture should be used with care where domestic fowls are apt to feed, as there is danger of poisoning them. However, Dr. Morrill* reports that chickens will not eat this poison mash and that there is no danger to poultry when it is scattered broadcast. His report is as follows:

"Experimentation has shown that there is no danger to poultry from eating the bran mash if it is scattered broadcast. The writer has seen no dead wild birds over ground that was treated. One season a pan of the prepared bran mash was exposed where chickens could get it if they

*"Grasshopper Control," N. Mex. College of Agriculture and Exp. Sta. Bul. No. 102, 1916, pp. 29-30.

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wished. Only occasionally would one peck at the bran and then only desultorily. None showed any signs of poisoning.

"Reports have come to the writer of chickens dying from eating grasshoppers, both alive and poisoned. Such deaths were evidently due to over-eating of a food to which the fowls were not accustomed."

Experiments were conducted the past season in Rio Grande County relative to the liability of poisoning pigs and cattle, and no ill resulted. *Figs. 2 and 3.) These experiments consisted in letting pigs and cattle graze on areas over which bran mash had

Fig. 2.—Part of a dairy herd in the San Luis Valley, where experiments were conducted relative to the liability of poisoning domestic animals by use of Paris green-bran mash, when properly applied in grasshopper control, 1916. (Original).

been strewn. In one case, 135 hogs grazed on 15 acres of poisoned alfalfa. On the third day, one pig died, but the post mortem examination showed no signs of poisoning. However, some stock died from poisoning, but upon investigation it was found, in all cases, that the poisoning occurred thru carelessness. One case, for instance, was where two calves died from licking a tub in which the poison mash had been mixed. This tub was left in the yard where the calves were running. Had it been cleaned, or turned upside down, the poisoning would not have occurred.

The following Kansas formula for poisoned bran mash for grasshoppers, developed by Professor M. F. Dean, is highly recommended by all who have used it, and gave decided results the

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Fig. 8.—Part of the 553 hogs grazing on alfalfa after Paris green bran mash had been sown to control grasshoppers at the rate of eight pounds per acre. No animals were poisoned. (Original).

past season in the grasshopper control in the San Luis Valley and elsewhere:

Paris Green	3 pounds
Bran	50 pounds
Syrup (a cheap grade)	1 gallon
Water	5 gallons
Lemons	10

Mix thoroughly the bran and Paris green while dry; dissolve the syrup in the water; squeeze the lemons into this, and finely chop the peel and pulp and add them also; pour this mixture into the bran and Paris green and stir so as to dampen the mash thoroly. Then sow broadcast as thinly as possible. The above amount will cover, if properly applied, 6 acres of ground.

This Kansas formula has been used and checked with four other formulas: Bran, Paris green and water; bran, Paris green, syrup and water; bran, Paris green, syrup, lemon extract and water, and bran, Paris green, salt and water, and the results were decidedly in favor of the Kansas formula.

DISEASES

Grasshoppers, like other animals, are susceptible to diseases. There are two or three known to attack them:

First.—A fungous disease (*Empusa grylli* Fres.) (Figs. 5 and 6), which has been reported to be successful in grasshopper control, but later experiments have proved it to be of no practical value. It appears that under favorable conditions this disease will appear, with more or less virulence, and spread with

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sufficient rapidity to cause the destruction of a large number of locusts.

Fig. 5.—Grasshoppers killed by the grasshopper disease, Empusa grvilli Fres. Note how they cling in clusters at the top of the dead grass.

Several years ago the so-called "South African grasshopper fungus" was distributed to a large number of farmers in the State for trial against grasshoppers, and several very favorable reports were received, but the attempts at this Station to inoculate grasshoppers and spread the disease were an utter failure, both in the breeding-cage where the conditions of heat and moisture could be controlled, and in the fields. In no instance was any substantial evidence found that a single hopper had been killed by the fungus. It was decided that in every case reported, the hoppers were killed by the disease *Empusa grylli*, first mentioned above, or by parasites, and not at all by the fungus that was distributed.

A very striking peculiarity of *Empusa grylli* Fres. is, that it causes the hoppers to climb to the tops of the stems of alfalfa,

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Fig. 6.—Grasshoppers killed by Empusa grylli Fres clinging to oat heads, Trinidad, 1916. (Original).

sweet clover, or other plants, where their dead bodies remain for days and weeks. (See Figs. 5 and 6.)

Professor Sacket*, bacteriologist of this Station, makes the following statement relative to *Empusa grylli* Fres.:

"Experiments carried on in co-operation with the Division of Entomology have demonstrated that the gresshopper is not susceptible to the organism when brought in contact with the ordinary form of the fungus, such as is obtained from the bodies of dead grasshoppers. In these experiments to which I refer, the grasshoppers were literally fed with the fungus, and the pure culture was spread upon their bodies. More than this, grasshoppers free from the disease were placed in breeding-cages with sick grasshoppers and grasshoppers dead of the disease, but, in spite of these numerous attempts to infect them, all remained healthy."

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*Twenty-fourth Annual Report, Colorado Agricultural Experiment Station, p. 20.

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Second— A bacterial disease (*Coccobacillus acridiorum* D'H.) was reported by D'Herrelle as having worked successfully in Argentina. Later experiments with this organism, both in the Philippine Islands* and in South Africa, have proved it useless after the infection of grasshoppers in the field.

Under artificial conditions, such as are found in a laboratory, these diseases may possibly be applied with good results, but as yet, no disease organism has been found that can be artificially applied with success for the destruction of grasshoppers in the field.

WORK OF 1916

During the past season, the losses caused by grasshoppers in Colorado were particularly large. Word was received from various parts of the State reporting outbreaks and requesting information relative to their control. The prevailing condition that favored this increase of hoppers is not exactly known, but in every locality where grasshoppers occur this same increase may be looked for in any season favorable to insect development.

The value and necessity of organization and co-operation to control these serious outbreaks of grasshoppers was early recognized in the southern part of the State, the first request coming from County Agent C. E. Smith, of Trinidad, Las Animas County, June 1. On June 10th, a like request was received from County Agent E. H. Thomas, of the San Luis Valley. Later, these were followed by County Agents W. H. Lauck and G. C. Burckhalter of El Paso and Morgan Counties, respectively, and others.

In Las Animas County and the San Luis Valley, the prevailing opinion for a time was that the remedial measures recommended by the county agents, such as sprays and poisoned baits were not effective. This was due to the fact that all the grasshoppers in a given locality were not immediately killed and those that were poisoned had crawled out of sight in secluded patches of grass or under rubbish and died.

An inspection of the farms about Trinidad and the adjacent communities revealed the fact that the grasshoppers were appearing in alarming numbers. At the evening meetings held at various places to discuss the situation it was ascertained that the county had had no previous outbreaks that would necessitate remedial measures. While the people were very enthusiastic, they seemed slightly skeptical as to the control of this pest. The demonstrations held at various parts of the county were always at-

*"A Test of the *Coccobacillus acridiorum* D'Herelle on Locusts in the Philippines," Philippine Jr'l of Sci., X, No. 2, Sec. B. Tropical Medicine, March, 1915, pp. 163-176.

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tended by a good representation of the community, but the results obtained were not as satisfactory to the minds of the farmers as they should have been. This was due to the fact that the grasshoppers were, in every case, just hatching, thus furnishing a fresh supply over a period of time longer than the effectiveness of the poison. The hoppers being very small, from newly hatched to not over one-half grown, when killed, soon dried and were blown away, rendering it almost impossible to find any dead ones, and with the increasing supply of newly hatched ones it appeared as though the remedy was of no avail.

It was ascertained that Mr. C. E. Smith had made an application of the Kansas formula for bran mash on a small garden tract near Trinidad when the hoppers were over one-half grown. Here the results were clearly in evidence. Previous to the application, the hoppers were in a bean and cabbage garden in alarming numbers. Investigation showed these fields free of hoppers. In the adjacent, uncultivated, weedy areas they were plentiful, but up to the line of poison, or where the bran mash had been spread, they disappeared entirely.

Through the efforts of County Agent E. H. Thomas of the San Luis Valley, it was found that several methods of grasshopper control were in progress, such as sprays, poison bait and the hopper dozer.

The condition of hatching was about the same as in Trinidad, but the hoppers were slightly larger, and the same general opinion as to the effectiveness of poisons prevailed. However, the poisons were doing their work, but the hoppers dying in secluded places made it appear otherwise.

At the "West Side Farm", Mr. McArthur had sprayed a fifteen-acre tract of alfalfa with Paris green and reported his results as negative. Upon a close inspection it was found that the spraying had been very effective. On making various examinations thruout the field, it was ascertained that there were, on an average, 25 dead grasshoppers for each square foot of area. Figuring from the size of the hoppers in question, this gave a total of 5 bushels of dead hoppers per acre. Mr. McArthur had previously stated that, in a previous inspection made by him, he found only three dead hoppers. This was due to the fact that he did not know where to look for them. However, he admitted that the number of live hoppers had decreased materially, but it was his opinion that they had migrated to an adjacent field. The apparatus used in this experiment was an ordinary barrel spray with a series of 13 nozzles attached. (Fig. 7.)

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Fig. 7.—A 18-nozzle beet spraying machine. The type that was used in the grasshopper campaign, 1916, San Luis Valley. (Original).

In fields where the Paris green bran mash had been applied and reported ineffective, an estimate as to the efficiency of the poison was made, and it was found that the dead hoppers averaged 37 to the square foot. On computation, it was found that, at this rate, there would be about 9 bushels of dead hoppers per acre.

The general prevailing opinion at that time was that the hopper dozer was more effective than the poison. This was undoubtedly due to the fact that the fruits of their labor were discernible and not scattered, as was the case with the poison. However, estimates showed that the spray and the poison bait were at least four times as effective as the hopper dozer.

Demonstrations relative to mixing and applying sprays and poisons in various communities were held, and always with a good attendance of interested farmers. Several trips were made to fields of peas, part of which had been plowed in the early spring, and the remainder left uncultivated, the peas being simply drilled into the old stubble as is the common custom in that vicinity.

The plowed areas demonstrated quite clearly the effect of early spring or fall cultivation for the destruction of eggs, as there were very few, or in most cases, no grasshoppers in the cultivated plots, while where the peas were simply drilled in the stubble, there appeared about as many hoppers as in the uncultivated fields of that vicinity.

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An inspection of the infested areas of El Paso County revealed the fact that the same general opinion prevailed as in the San Luis Valley. However, it was found that the main trouble was in the mixing and application of the poison. The mixtures examined were poorly made, the syrup having been poured directly into the bran and Paris green, consequently causing it to be formed into small balls, so that it could not be applied properly. The applications were made from a tub of this mixture placed in the back of a buggy and driven promiscuously thru the fields.

Too much stress cannot be laid upon mixing and applying the poison, as the success of the application depends entirely upon these operations. If the points relative to mixing and applying, heretofore discussed, are carried out in detail, I believe there need be no trouble in controlling a plague of hoppers or from poisoning animals.

Shed in which was mixed by hand a large quantity of Paris green-bran mash during the grasshopper campaign, 1916, San Luis Valley (Original).

The conditions in Pueblo County were somewhat different than in the other infested territory, they having had a slight outbreak of hoppers two years previous and being informed as to remedial measures. The outbreak was not very alarming, but in most places where hoppers occurred, the bran mash had been applied with good results.

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The campaign was taken up by County Agent Stanley V. Smith, thru the county commissioners, who furnished a given amount of Paris green to those who would apply it. This Paris green was distributed from various centers, consequently it had a wide distribution and was applied in many localities, but not in all cases where it should have been.

One field on Orchard Mesa was very badly infested, there being 7 acres of alfalfa which was almost entirely defoliated. The owner was distributing Paris green for the county and did not deem it necessary to apply it to his own land. Adjacent to this infested field were 15 acres of beans. The idea of the owner was to let the hoppers eat his alfalfa in order to save the beans. Had he applied the Paris green bran mash, he could have saved the entire crop. The yield would have been at least five tons, and hay was then selling at $13.00 per ton. This individual was paying a toll of at least $65.00 to the hoppers and not killing one, where he could have made an entire clean-up for $5.00, had he applied the bran mash.

At the time of visiting the above place, the hoppers were leaving the defoliated alfalfa field and entering the bean patch around the edges. In all probability the entire bean crop was destroyed by the grasshoppers.

In accordance with the pest law, several pest districts were formed thruout the State, three in the San Luis Valley, two in Rio Grande, one in Saguache County, one in the Fountain and Mesa district in El Paso County, and three were arranged for in Logan County, giving in the latter an almost continuous district thru the Platte Valley from Messex to Red Lion. This covers the principal irrigated section of said county.

On July 1, a second trip was made to the San Luis Valley at the request of the commissioners of Rio Grande County, to further the work commenced in the grasshopper investigations and assist Mr. W. E. Kistler, who was to be the pest inspector for the above mentioned districts.

The first duty of the inspector was to check over various previously poisoned places to determine the effectiveness of the Paris green bran mash. The first forenoon, four farms were visited where there had been from 70 to 105 acres each, poisoned three weeks previous. The results were surprisingly good. In three out of the four farms visited, a complete eradication, instead of a control, had been effected. This was especially true on Mr. Tiner's premises. Mr. Tiner was the first man in that section to take hold of the poison bait method for grasshopper control, and

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it was upon his farm that the first demonstrations were conducted. At that time the hoppers were so numerous that a complete devastation of his crop was threatened. On checking over the results, three weeks later, one had to go, on an average, from 30 to 60 steps before seeing a live grasshopper.

In a great many places in the valley, numerous pigs are raised and pastured on alfalfa, and in most cases these fields were badly infested with grasshoppers. The owners of such fields were skeptical about treating these fields for fear of poisoning their stock. While some were not afraid of the Paris green directly, they were afraid that the hogs would eat the dead hoppers and thus be poisoned. However, this point was cleared by Tiner, Drake, Arthur and Davis. Mr. Tiner had 28 spring pigs (Figs. 2 and 3) feeding at all times on the poisoned area, and the other men had 135, 243, and 175 pigs, respectively, of all ages, feeding upon grasshopper-infested pastures that had been sown with Paris green bran mash, and one pig died. The owner thought this pig was poisoned, but it is possible that one pig out of 553 could have died from some other cause than poisoning from the bran mash.

In the counties of Rio Grande and Saguache, San Luis Valley, practically all the infested land, where control work was conducted, was organized into pest districts and the farmers used the Paris green bran mash according to the Kansas formula. All materials used were purchased in large quantities and distributed from a central point, ready mixed.

In Rio Grande County, Mr. Fuller, a druggist of Monte Vista, furnished most of the poison used. This he mixed, upon application, and furnished to the farmers at a less rate than they could buy the materials at retail and do the mixing themselves. During the campaign he mixed and distributed:

6,550 pounds of Paris green
38 tons of bran
41 cases of lemons
1,380 gallons of syrup

However, this does not represent all the materials used in the two pest districts in his county, as a large quantity of Paris green was obtained from the sugar factory and some from Center.

In Saguache County, Mr. Sumpter, a druggist, furnished and mixed the materials used. An exact account of the amounts used was not kept, but it is safe to estimate that the quantity used was at least half that of Rio Grande Countty. A machine mixer, (Fig. 8) was used by Mr. Sumpter which greatly lessened the work of

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mixing the poison. It consisted of a cylinder sufficiently large to hold at least 400 pounds of bran, revolving upon an axle, the power furnished by an old Ford machine. Only 100 pounds, dry weight, was mixed at a time. This gave plenty of room for mixing. The time required to mix and sack one filling was eight minutes.

Fig. 8.—Sumpter mixing machine used to mix Paris green-bran mash, Center, Colorado, 1916. Time required to prepare, mix and sack 100 lbs., dry weight, of the bran mash, eight minutes. (Original).

In the San Luis Valley and elsewhere where the Kansas formula for poisoned bait was used, the results obtained, as a whole, were entirely satisfactory, the County Agent, E. H. Thomas, reporting a gain of from $3 to $5 per acre on something over twenty thousand acres in favor of the treated areas. In many cases a complete eradication, instead of control, was effected. The results are shown in the table on pages 28 and 29, which is compiled from information obtained thru a circular letter.

The question of grasshopper control is a very important one in any district where grasshoppers occur in sufficient numbers to warrant remedial measures. It is hoped that the results of our experimental and field demonstration work will convince the most skeptical person that the destruction of this pest in future outbreaks will be a very simple matter.

Farmers living in districts where grasshoppers are destructive or threaten destruction to crops, should organize at an early

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date and order a sufficient quantity of necessary materials for distribution when necessity demands. The mixture should be applied in the evening, or in the early morning before the hoppers begin to feed. In fields where the hoppers are localized, the poison should be scattered over the infested areas. In fields where a total infestation occurs, it should be applied everywhere and at the rate of about 8 pounds to the acre.

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THE FOLLOWING TABLE IS A SUMMARY OF THE INFORMATION OBTAINED IN AUGUST, 1916, RELATIVE TO THE RESULTS OF THE GRASSHOPPER CAMPAIGN IN THE SAN LUIS VALLEY, COLORADO.

The information in this table was supplied by the farmers whose names appear therein and the statements in the column headed "Remarks" were taken from their communications.

REPORTED BY	ACREAGE		Stock Poisoned	Grass-Hoppers Appeared	Land Plowed	REMEDIAL MEASURES		Results	REMARKS
	Cultivated	Treated				What Used	Time Applied		
J. McLodgan	160	160	None	June	Spring & Fall	Bran Mash	July	Good	Only a few hoppers left.
Alice B. Cheney....	925	925	None	....	Spring & Fall	Bran Mash	July	Splendid	
Anna McCormick ..	155	100	None	May	.....	Bran Mash	June	Good	Ravages effectively stopped. Killed cutworms also.
F. S. Jones.....	144	115	None	May	Spring & Fall	Bran Mash	May	98% perfect	Used dozer on pasture. Partial success.
Henry Seth	155	120	None	June	Spring only	Bran Mash	June	Killed them all	
A. J. Stoeber.....	249	100	None	April	Spring only	Bran Mash	May	Good	Poisoned pasture; lost no stock.
A. O. Miner.....	170	120	None	May	Spring & Fall	Bran Mash	June	Fine	Results entirely satisfactory
V. Drake	310	250	1 pig	May	Spring only	Bran Mash	June	Good	Poisoned pasture, grazing 135 head hogs; lost one.
I. P. Taylor.....	160	103	None	May	Early Fall	Bran Mash	June 15	Pest practically destroyed	Very favorable.
C. W. Myers.....	500	500	None	May	Spring & Fall	Bran Mash	June	Favorable	Bran mash a good remedy.
J. M. Arthur.....1975		1975	None	April	Spring	Bran Mash	June & July	90% killed	Poisoned pasture. Lost no stock. Have 243 head.
E. H. Johnson.....	150	130	None	April	Spring	Bran Mash	June & July	75% killed	Results very satisfactory.
W. H. Towne.....	...	160	None	June 1	Spring	Bran Mash	June	Good	Dozer used, but abandoned it for poison.
Fred Schield	157	17	None	July	Summer 1915	Bran Mash	June	Favorable	
C. F. James.....	885	6	None	June	Spring & Fall	Bran Mash	....	Good	

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G. W. Maxey.....	128	60	None	June	Spring & Fall	Bran Mash	....	Fair	Lost a few chickens.
E. C. Harper.....	116	80	None	May 15	Spring & Fall	Bran Mash	....	Very good	
E. G. Mathias.....	160	150	None	....	Spring & Fall	Bran Mash	....	Good	Sawdust used with fair results
W. E. Kistler.....	290	100	None	June	Spring	Bran Mash	July	Good	Used 200 lb. sawdust mixture; results good.
Cris Selters	503	100	None	June	Spring	Bran Mash	June	Fair	Results fair.
Felix Kaiser	145	30	None	June	Spring	Bran Mash	July 7	Very good	Plowing destroys many eggs.
James H. Neeley....	148	113	None	May	Spring	Bran Mash	....	Very satsfac-tory	Used spray, 2 lbs. Paris green to 1 bbl. water; results poor.
M. Metz	395	130	None	May	Spring	Bran Mash	June	Very good	Poisoned mash, best control. Not many left.
W. L. Starbuck....	450	60	1 calf*	May	Spring & Fall	Bran Mash	June	Very good	Got to mixing pan and licked it.
W. A. Elwood.....	110	30	None	July 1	Fall & Spring	Bran Mash	July	Good	No hoppers on fall plowed land.
C. G. Wright.....	296	150	None	May	Fall & Spring	Bran Mash	June	Very favorable	Land fall plowed had scarcely any hoppers.
J. W. Davis.....	368	368	None	May	Fall & Spring	Bran Mash	June	Good	175 hogs on poisoned pasture. Lost none.
O. A. Cramer.....	335	175	None	April	Fall & Spring	Bran Mash	July	Good	Used with good success elsewhere.
Seth Methias	440	440	None	April	Spring	Bran Mash	....	Very favorable	Used dozer; results good.
H. M. Wright.....	155	140	None	June	Spring	Bran Mash	June & July	Very good	
J. Becraft	260	40	None	May 15	Spring	Bran Mash	June	Extra good	Results very favorable.
E. W. Jackson.....	110	110	None	April	Spring	Bran Mash	May	Very favorable	Used 700 lb. poison, poisoned pasture; lost none of 78 head.
W. W. Wright.....	605	100	None	May	Fall & Spring	Bran Mash	....	Good	
Center	160	160	None	....	Fall & Spring	Bran Mash	....	Good	75 hogs on poisoned alfalfa; Lost none.
T. P. Warren.....	130	50	None	May	Spring	Bran Mash	June	Very good	
R. C. Dillon.....	155	20	None	....	Spring	Bran Mash	....	Very favorable	Used 200 lbs. on 20 acres.
E. E. Newmeyer....	205	150	None	May	Fall & Spring	Bran Mash	June & July	Good	Results very favorable.
B. H. Smith.....	150	140	None	June	Fall & Spring	Bran Mash	June	Cleaned up	

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The Agricultural Experiment Station

OF THE

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BEANS IN COLORADO AND THEIR DISEASES

(Revised Edition of Bulletin No. 226)

By

ALVIN KEZER & WALTER G. SACKETT

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BEANS IN COLORADO

By ALVIN KEZER

SUMMARY

Beans are becoming an increasingly important crop in Colorado.

They are well adapted for both dry farming and irrigated conditions.

The "Plains" section is almost entirely adapted for the growing of beans. They do well also in mountain valleys at altitudes not to exceeded 7,000 feet. In many localities 6,000 feet is too high for their proper growth because of the shortness of the season and the tendency of early and late frosts.

Beans are an excellent cash crop, with a well established market and market facilities.

In Colorado the chief market bean is the pinto. Navies, teparies and the Red Mexican or Red Miner are grown to some extent. A white Mexican bean, closely related to the pinto is gaining popularity in certain sections.

Many beans are being grown under contracts with seed houses. These beans represent a number of different varieties produced for seed, because of peculiar advantages for clean seeed which the semi-arid climate possesses. The chief danger of seed bean contracts is injury to standard markets by growers attempting to throw rejected seed onto the standard markets.

Beans are a hot weather crop, consequently, they should not be planted until frost danger is past. In most localities this will be approximately June 1st.

Planting should be shallow. Planting may be done preferably with the regular bean planters. Corn planters with bean plates may be used. The ordinary grain drill, stopping the proper number of holes, is feasible where necessity requires.

Beans are a shallow rooted crop. Consequently, the first cultivation should be the deeper. Later cultivation should be as shallow as the first cultivation or even shallower. Cultivation should not be over 3 inches.

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In irrigated districts, beans should be irrigated so as to keep the beans growing. A very dark green color is generally indicative of a need of water. Beans should not be irrigated later than full bloom on most soils, as later irrigation will delay maturity and not increase yield materially. Ordinarily one to two irrigations are sufficient.

Harvesting should be done preferably with a bean harvester. This is especially true where any considerable acreages are planted. On very small acreages, they may be harvested by taking the mold board off the plow or by using a shovel.

Beans shatter in thrashing very easily, consequently the bean huller should be used unless the acreages are very small. There are special attachments which may be used on the regular grain separator, provided the separator is run at very low speed. Patches of one to two acres can be thrashed with a flail as cheaply as by machine unless a machine is near. Machines for cleaning are available and should be used, as they increase market value.

Pinto beans, the chief Colorado market sort, will average from 300 to 800 pounds under dry lands and may yield as high as 1,800. The same beans will average from 1,200 to 2,000 pounds under irrigation, and may yield as high as 3,000 pounds or even above.

Market prices may be increased by putting beans up in uniform packages and having them thoroly cleaned.

Bean straw should be carefully saved, as it is a valuable feed. This applies especially to dry lands.

Beans make an excellent rotation crop. Wheat on the dry land after beans will do as well as after clean summer fallow most seasons.

The yield of beans may be increased and their quality improved by wise field selection.

Seed beans should be hand picked to get uniform quality and freedom from disease. Care should be taken not to plant beans which have been frost bitten.

There are many diseases which affect beans. The best methods of controlling these diseases is the picking of clean seed and following a rotation. Beans should not be planted on the same land two years in succession. Two to three years should elapse before beans are again planted on the same land.

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INTRODUCTION

The Colorado bean acreage has been steadily growing for the last ten years. The rate of growth in 1915 and 1916 has been as great as in the previous eight years. According to the Bureau of Statistics, United States Department of Agriculture, 38,000 acres were grown in Colorado in 1916, a jump from 21,000 acres in 1915, and 20,000 acres in 1914. The total production of the State in this period has jumped from 18,000,000 pounds to 25,440,000 pounds, in round numbers. In other words, the acreage has increased 81% and the total production has increased in the same period about 41%. The 1916 yield per acre was low on account of one of the worst drouths in the history of the Colorado Plains. The seasons of 1914 and 1915 were especially favorable, with high average acre yields. In 1917, 243,000 acres of beans were planted in Colorado. Owing to poor farming, very unseasonable weather conditions, hail and other vicissitudes only about 190,000 to 200,000 acres were harvested. The difference between the area planted and the area harvested represents the mortality due to unfavorable conditions. Of this area about 40,000 acres was irrigated. There were grown for seed, under contract with seed houses, about 20,000 acres. These seed beans represented about a dozen different varieties and were produced mostly for eastern seed houses. The total 1917 yield was approximately 90,000,000 pounds.

Beans are well adapted for growing in nearly all sections of the plains. Beans are a hot weather crop and as a consequence must be produced in the frost-free period. To successfully produce a bean crop, the season should be at least 95 days in length; 95 to 100 days should be the minimum. A season of this length is seldom found above an average of 6,000 feet in elevation. There are localities where the slopes are favorable and the soils sandy, where the seasons are somewhat longer, permitting the production of beans at altitudes as high as 7,000 feet. If the season is bright and rather warm, some of the early varieties may be matured in as short a season as 60 days. A cloudy season, however, always lengthens the growing period. Cool, cloudy weather may extend the growing season, especially if rains accompany these weather conditions or if irrigation is given. In such cases the season required for maturity may be as long as 130 days, too long for many sections even 6,000 feet in altitude.

The pinto bean, which formerly went under the name "Mexican", is by far the most important market bean, as it exceeds in acreage and total production all other beans produced. The seed industry beans, which are of numerous varieties, are the only ones which begin to compete in acreage with the pintos. These seed beans are largely produced under contracts with seed houses and consequently do not reach bean markets.

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While beans may be successfully grown practically anywhere on the plains at altitudes below 6,000 feet, they are most abundantly grown in Weld, Logan, Morgan, Las Animas, Washington, Otero, Bent, Prowers, El Paso, Adams and Arapahoe Counties. They may be successfully grown in other places, but development in other regions has not yet been carried to the extent which these counties have made. The realization of the value of beans as a cash crop, and the ease with which they fit into a rotation by throwing in an annual cultivated crop, will very likely tend to increase their general production.

VARIETIES

The chief market variety is the pinto. The pinto bean was formerly called the Mexican. This name, however, is inappropriate, as there are numerous other Mexican varieties. The name "Mexican" as a consequence did not mean any definite bean. "Pinto" applies to a specific bean.

The pinto bean is about the same size and shape as the kidney bean, so well known as a garden variety. The pinto is buff-colored, is speckled with tan to brown spots and splashes. It is further characterized by a characteristic yellow rim or border about the germ. In many places in the southwest the pinto is called the Mexican tick bean. In other places in the southwest it is known as the Colorado bean. In a few places it has acquired the name army bean. The name "pinto", however, has become so well established that it should be universally used.

While the pinto is the chief market bean, other beans are grown and frequently do well. The navies are grown and produced to a small extent—both the pea bean and the little navy. For garden purposes considerable quantities of kidney beans and "snaps" are grown. In most of our territory the season is too short for the proper development of limas; consequently, they do not figure in our bean problem to any extent. In parts of Colorado the Red Mexican or Pink Mexican, or Red Miner, is grown. This bean, however, is more extensively grown in New Mexico and Arizona and other points of the Southwest than in Colorado.

PREPARATION OF THE SOIL

Beans will grow on almost any kind of soil, from adobes to light sandy loams. They do best, however, on warm, sandy loams and sandy silts. Preparation of the soil for beans should commence prior to the season in which the beans are grown and should take into consideration proper rotation and manuring. The soil should be prepared by plowing. Wherever fall plowing may be done without danger of serious fall blowing, the soil should be plowed in the fall. In the spring

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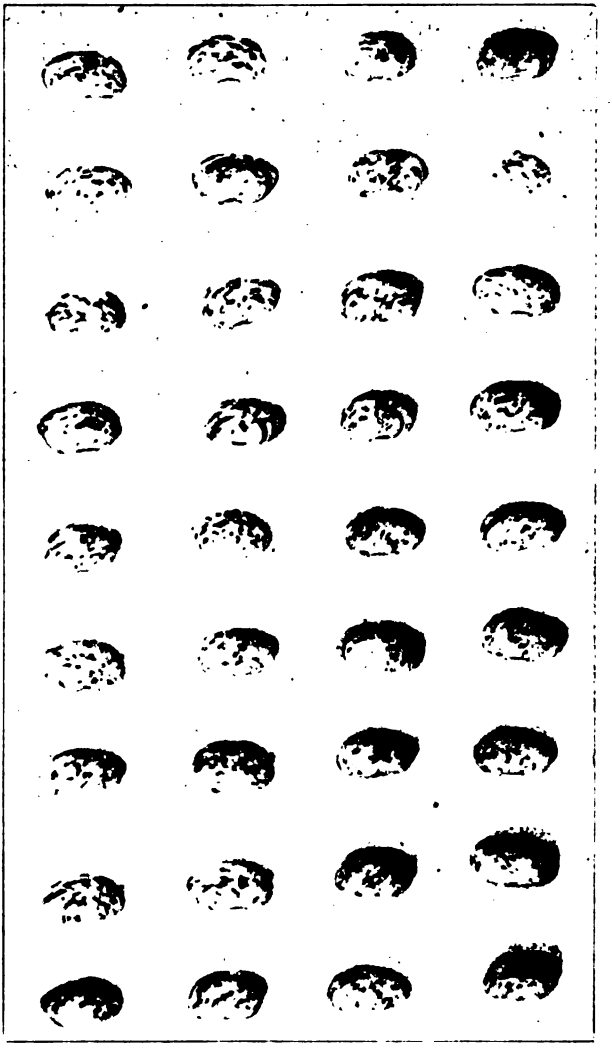

Colorado Pinto Beans about natural size (Courtesy C. & S. Ry.)

this land should be worked down into a seed bed, making as good a seed bed as would be made for beets or corn. Where spring plowing is done it should be done early.

Beans respond to good preparation. Consequently enough attention should be paid to disking, harrowing and compacting the seed bed. In some sections listing has been attempted as the method of preparing the soil for bean planting. Listing, however, is poor practice, except upon soils which cannot be safely plowed, because of their very strong

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tendency to blow. Where the land is prepared by listing, there is a tendency to slow up the development of the crop and delay maturity. In addition to these handicaps, beans planted by the listing method are more difficult to harvest; especially if there is damp weather during the harvest there is likely to be much damage to the pods by coming in contact with the soil. The tendency to pick up adobe soil or stones is increased at harvesting time. If listing is done at all, it should be very shallow so as to make the furrow to be filled about the growing plants as shallow as possible.

It is not always necessary to plow land in preparing a bean seed bed. Where the land was well plowed the year previous and in wheat, a good seed bed may be prepared without plowing, provided the wheat stubble is disked right after the binder to keep down weeds in the fall. The spring preparation may consist of disking when the weeds start, which will destroy the weeds and prevent the formation of a crust, and then disking and harrowing immediately before planting. After a cultivated crop such as corn, which has been well cultivated, a seed bed may often be prepared by disking and harrowing.

On irrigated lands after sugar beets or potatoes, it is not necessary to plow in preparing a bean seed bed. Disking, leveling and harrowing will be sufficient in these circumstances.

PLANTING

Care in Selecting Seed Beans.—The importance of getting good seed beans is sufficient to warrant special care in picking the seed. It is worth while taking a little extra care in Colorado on account of the short seasons. In many localities there is danger of beans being frost bitten in the early fall. Sometimes this light freezing will very materially weaken the germ so that the crop will have very small germinating power, altho the frost may not be sufficient to injure the beans seriously for market purposes. Care should therefore be taken not to use beans for seed which have been frost bitten before full maturity.

Many of the diseases which affect beans leave spots on the beans themselves. One of the most effective remedies in combatting bean diseases is to pick out plants for seed which are not affected by the disease. Accordingly all seed beans should be from plants selected in the field and hand picked. Plants having discolored beans with strange colored spots should be rejected, planting only from those having bright, clean seed.

These statements hold, no matter what variety of beans is planted.

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Time to Plant.—Beans are a hot weather crop. Seed is injuriously affected if it is planted in cold soil. Germination will not take place while the soil is cold, and if the soil happens to be wet enough, rotting may take place before the soil warms up sufficiently to permit germination.

Beans will not stand any frost. The very slightest degree of frost is apt to kill them entirely. On account of these reasons, beans should not be planted until the soil is thoroughly warmed up. In most Colorado sections this will be the last week in May or early in June. Successful plantings have been made as late as the first week in July, but the grower is tempting fate too much to make a practice of such planting, as frosts are likely to occur as early as the 25th of August.

While pinto beans and some of the teparies and a few of the Mexican and Indian varieties have been matured in 60 days or less, it normally takes about 90 days to mature a crop even for these short-season beans. In those seasons when frosts hold off until late in the fall, late planting will often make a crop, but frosts do not always hold off until late.

Method of Planting.—If there is any considerable acreage of beans to be put in, a bean planter should be procured, or a corn planter with bean plates. In Colorado beans should always be planted in drills so that the bean planters or corn planter should be so arranged as to drill the seed one in a place. It is possible to make use of a grain drill by stopping up the proper number of holes, in fact, many beans are successfully planted with such an implement. The type of grain drill having a revolving cup feed is adapted for this kind of planting.

Most of our grain drills have 7 or 8 inches between the drill holes. Stopping up three drill holes would therefore plant 28 inches apart, which is about right for irrigated planting. With a 7-inch drill, stopping up 5 holes, that is, leaving open the first and sixth drill, would plant 42 inches apart, which is about right for dry land. Some dry lands are strong enough to justify planting 36 inches apart. Stopping up four drill holes, leaving the first and fifth open, would plant 35 inches apart, which is about right.

Under irrigated conditions the rows should be about 28 inches apart. On dry lands, they should be from about 3 to 3½ feet apart. Under very dry conditions it is sometimes advisable to plant 7 feet apart and cultivate all of the intervening space. For irrigated conditions the drill should be thick enough to make one plant every 4 to 6 inches. This will require around 30 to 35 pounds per acre of seed for pinto beans. It will require a greater number of pounds for larger

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beans and a somewhat smaller number of pounds for the small pea beans.

For dry land conditions beans should, under normal conditions, be planted in rows about 3½ feet apart and in drills in the row 10 to 12 inches apart. If dry land conditions are a little severe, or uncertain, the space can be made a little further in the drills, say from 12 to 16 inches. According to the rate of drilling, it would take from 8 to 20 pounds of seed to plant an acre under dry land conditions. For an average planting, probably about 15 pounds per acre will be used. Where the rows are made 7 feet apart, under very severe conditions, the planting should be 6 to 8 inches in the drills.

Of the many beans planted only a few are put in by plowing shallow and dropping the beans in every third or fourth furrow, covering the beans by plowing and then packing and harrowing afterwards to compact the surface soil over the beans. This is not a good practice, but can sometimes be used in very small patches. Where large plantings are made, a bean planter adjusted to plant in exactly the proportion desired, should be used.

CULTIVATION

Beans of all varieties are rather shallow-rooted surface feeders. Consequently all cultivation after the crop starts should be shallow. The most important part of the cultivation should be done in the preparation of a seed bed. Immediate cultivation should commence about the time the rows can be seen in the field. Where the stand is extra good, beans may sometimes be harrowed a time or two if care is taken to do this work when the young vines are perfectly dry. If the soil

Cultivating dry land pinto beans in El Paso County

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is a little moist and the vines moist, the young vines will be found to be quite brittle so that harrowing will break off a large number. With the surface of the soil rather dry and the plants dry, the young plants are tough and will stand harrowing.

Some of the weeders on the market are excellent tools to use at this time.

The first cultivation with the regular cultivator should be the deepest. This first cultivation should not be over 3 to 4 inches deep. Later cultivations should be as deep or slightly shallower than the first cultivation. When the first cultivation is made, the roots have not extended very far into the space between rows. The stirring of the surface layer at that time by the cultivator makes a dry layer on top. If this is maintained the beans will root below the dry layer. Cultivation should be aimed primarily to keep down weeds and prevent the formation of a crust. Usually all cultivation should cease by the time the first pods commence to set. Sometimes the plants have grown enough so that cultivation should cease before this time. Care should be taken never to cultivate when the young bean plants are wet, as they are easily broken at such times, and when so broken are very susceptible to certain bean diseases. Under irrigated conditions cultivation should follow irrigation, as soon as the surface moisture and the plants will permit. The aim should be to prevent the loss of water by cultivation rather than to furnish water by excessive irrigation.

Irrigating Beans.—A study has been made of bean irrigation in eight Colorado counties. This study shows conclusively that it is fully as easy to over-irrigate beans as to under-irrigate them. As an average of all results obtained, two irrigations give higher yields than three or more irrigations. There was some difference as to quality of land; very open gravelly lands would stand more irrigation than sandy loams, loams and clay loams.

In irrigated districts which have a low precipitation and where crops must usually be irrigated up, it is good practice, especially on loam, clay and adobe soils, to irrigate the land before planting, thoroly watering the land at this irrigation. Just as soon as the soil can be worked after the irrigation, the soil should be harrowed, or disked and harrowed, leveled and planted. Cultivation should be depended upon to conserve the water supply. Irrigated in this way, two irrigations are more effective than three applied after the beans are planted. Cultivation should be resorted to rather than irrigation, to conserve the water supply.

In irrigated regions beans should be given water when they show a need for water, namely, when the plants show a very dark green and commence to wilt during hot periods of the day. If the plants are light green and growing vigorously, irrigation may often be delayed unless it is necessary to irrigate to get the water.

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Beans in irrigated districts will usually be planted in rows around 24 or 28 inches apart. The first step in irrigation is to use a furrow opener and make furrows between the rows. Water is run down these furrows under proper control, until the soil is moistened laterally and to a depth of at least 2 feet. This figure 2 feet is a relative one. Sometimes there is moisture enough in the subsoil at less than 2 feet from the surface when the surface needs irrigation. In such cases a lighter run of water will suffice. The last irrigation should very seldom be given after the blooming period; just as the plants are coming into bloom is as late as water should be applied in ordinary seasons, and on ordinary soils. Later irrigations delay the maturity of the crop and endanger proper ripening, because of possible frost injury. Such later irrigations do not materially increase the yield of beans.

The chief consideration, either on irrigated land or dry land, is good thoro cultivation. Such cultivation should be given as soon after irrigation as possible to get onto the land, and on dry lands such cultivation should be given after rains as soon as it is safe to work the soil. Cultivation should not be given after the vines begin to run, which is about the blooming period, as previously mentioned.

HARVESTING

All harvesting methods can be classified into hand harvesting and machine harvesting.

Hand harvesting is only adapted to small patches. Hand harvesting is usually done by either pulling the vines or cutting them off just under the surface of the ground with a sharp shovel. The vines thus pulled or cut off are shocked by means of pitch forks.

On sod land the ordinary type of blade bean harvester will not work on lands of such preparation. Hand harvesting has been necessary in the past. A few growers have overcome the difficulty by setting a revolving disk so as to cut off the plants below the surface of the soil. A special arm or frame has to be constructed to hold the disk at the proper angle and in the proper place. The disk, on account of its rolling motion, will not clog up with trash and chunks of unrotted sod.

The best machines for harvesting beans are the regular bean harvesters. These machines cut the bean plants off just below the surface of the ground and by means of fingers push two rows together into one harvested row. The most up-to-date machines have bunching devices on the machine which bunch the cut vines into small, neat bunches. These bunches can be dressed up a little by a man with a pitch fork, for curing. Many of the machines, however, have no bunching device. In this case the bunching must be done by hand.

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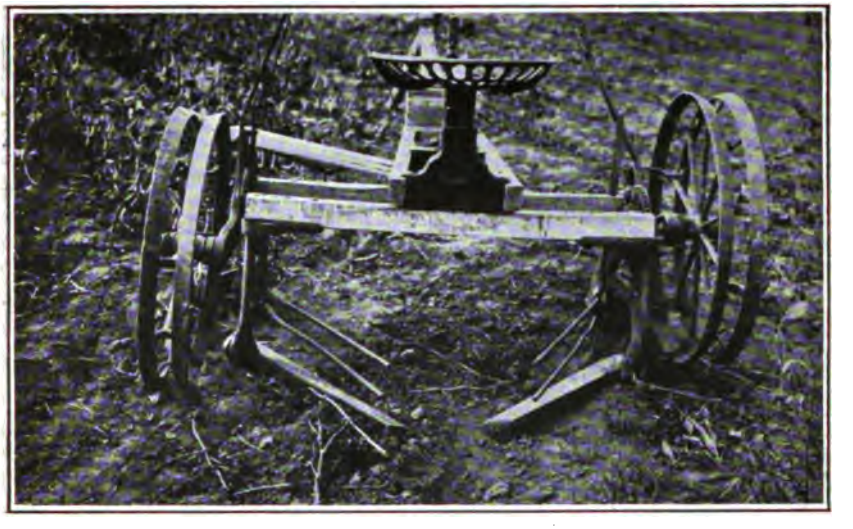
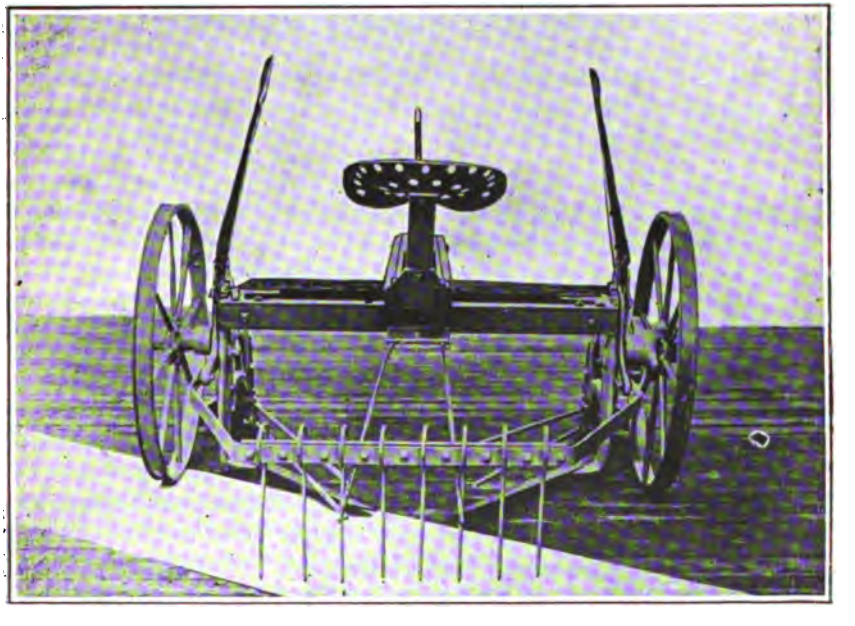


A common type of bean harvester



One of the newer bean harvesters with bunching attachment

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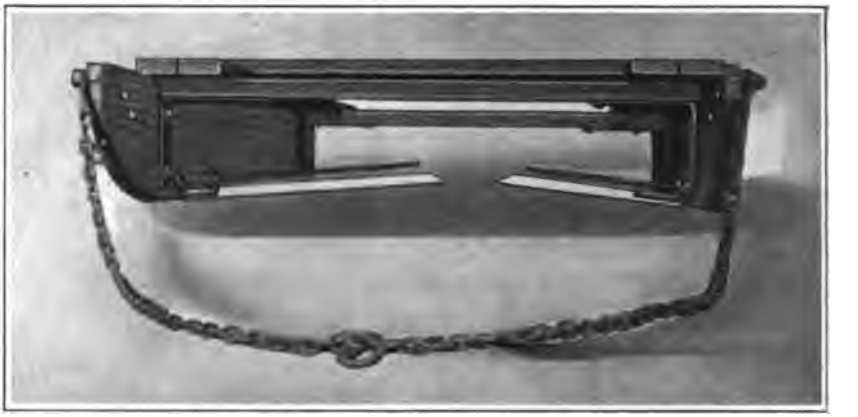

Home-made bean harvester (Photo by W. H. Lauck)

Men follow the machine with pitch forks putting the cut beans into neat shocks. Under Colorado conditions in practice the machines with the bunching attachment have not proved as successful as it was hoped. Some growers have found that if cut while the vines and pods are sufficiently moist, they can bunch the vines with a horse rake. This practice has only one disadvantage, namely, the bunches are usually too large for the proper curing and drying out of the vines and pods. A better practice is to collect the vines in small, rather flat bunches which can be easily turned over with the pitch fork in the hands of a single man. Such bunches cure readily and, if wet, can be inverted for drying. It has been found by experiment that a much higher quality of bean can be obtained by this method of bunching.

While a regular bean harvester is desirable and should always be used if there is any considerable acreage of beans grown, they may be harvested by using a breaking plow of the rod type, or by using a common sod plow with the mold board removed. Such expedients are much better than hand work on patches an acre or more in size, but should only be used on small patches where the size of the patch is not large enough to justify the purchase of a regular harvester.

Harvesting Period.—Opinions differ as to the proper time of harvesting. But experience and experimental work both show that if the beans are allowed to become completely ripe on the vine, heavy loss occurs from shattering. A good rule to follow is to harvest when the pods are turning yellow but have not yet dried out; at this stage there will usually be about half of the pods yellow ripe and a few still showing some green, providing the beans are ripening uniformly. When cut at this yellow-ripe stage, the beans will ripen up in the shock during the curing process and the loss in weight by drying out

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Another view of home-made bean harvester (Photo by W. H. Lauck)

is very much less than the loss in weight thru shattering if the beans are allowed to become too ripe.

Experience shows in the case of pinto beans that they may be cut while the pods are still green if the bean is plump and well formed, that is, completely developed but green in appearance.

Care of Harvested Beans.—The beans thus cut with the harvester should be made into small shocks. Experience has shown that a small flat shock, just large enough so that it can be completely inverted or turned over with the pitch fork in the hands of a single man, will be blown about less by winds and enables the beans to be cured up in a much more perfect condition than larger shocks. These small flat shocks are not injured so much by wet weather as they can be dried out easily and cheaply by turning the bunches. They are close to the ground and do not blow badly. Being small and thin, shocks of this character dry out very rapidly in the curing process. Consequently they can be stacked and thrashed in a much shorter period than if larger shocks are used. If it is impossible to thrash

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them when cured, it would be far better to stack them in neat stacks so as to prevent loss by blowing, discoloration from weather conditions and also to leave the land free for cultivation. If the beans have been properly shocked, there will be very little shattering in stacking as the stacking can be done early in the day, or loss may be prevented by covering the hay rack or bean rack with canvas. In building a stack a bottom should be made with straw and the stack should be topped out with straw and weighted. If straw or millet is not at hand to be used for this purpose, a stack cover of canvas or corrugated iron will be advisable if any considerable time is to elapse before thrashing.

The harvesting process, together with summer cultivation, leaves the land in excellent shape for fall planted crops such as wheat, or even for spring planted crops as plowing is not necessary after the tillage given the beans.

THRASHING

Beans split very easily unless handled with care. Split beans are docked on the market. Consequently, tools should be used which split the minimum of beans. It is for this reason that the regular bean hullers or bean thrashers should be used for thrashing the crop.

There are a number of manufacturers having bean hullers on the market. It is possible by using some of the modern attachments to thrash beans with the regular grain separator. This should not be done unless a bean huller is so expensive, acreage considered, as to make it inadvisable. Where the grain separator is used to thrash beans, special attachments are put in and the cylinder is run at a very slow speed. Usually all the concave teeth with the exception of one row are removed.

Where a grower has only one-half an acre, or one acre, it is sometimes easiest and cheapest to thrash out his beans with a flail. Fifteen to eighteen hundred pounds a day can be thrashed out in this way by a single man.

Very few of the thrashing machines on the market will properly clean beans for the market. Consequently, machines called bean cleaners have been devised to clean up the beans ready for marketing. If any considerable acreage is grown, it would pay to have a bean cleaner to clean the thrashed beans before they are put on the market. Where only small acreages are grown, neighbors might well co-operate in the purchase of a cleaner, as one cleaner would do the work for several small growers.

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YIELD

The Colorado pinto is the great market bean for Colorado. As has already been said, it is grown on more acres than all other kinds of beans combined. The average yield of pintos per acre on the dry lands in 1914 and 1915 was close to 800 pounds. In 1916 the average varied from 300 to 600 pounds per acre, with total failures in some neighborhoods. The season of 1916 was one of the driest in the history of the Colorado plains. The average yield of Colorado pintos on irrigated lands in 1914 and 1915 was 1,400 pounds per acre. In 1916 the average pinto yield under irrigation was close to 1,600 pounds per acre. Yields as high as 2,000 pounds per acre have been produced on the dry lands and as high as 3,200 pounds have been produced on irrigated lands. These higher yields are by no means average, but they show the possibilities of the crop when all conditions are made favorable. 1917 was a very unfavorable bean season. The spring was late, cold and wet which delayed planting. On the dry lands many sections received no rain for a three months period thereafter. Irrigated beans produced average yields better than ordinary but dry-land beans did not average over 200 pounds of beans per acre and

A good set of pinto beans; after a light frost

very few yields higher than 600 pounds per acre were reported. Some fields returned yields of over 300 pounds per acre without receiving any rain during their period of growth. Where these yields were obtained, the land had been plowed previous to the rainy spring. Where plowing was done after the rainy spring, low yields were uniformly obtained.

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MARKETING

One of the most important problems in the marketing of beans is to have a clean, high-grade, uniform product. Mixed beans, with discolored, broken beans, seriously dock the price. Since the pinto outyields most other beans in practically all the Colorado bean-growing sections, it should constitute the chief market bean.

Machine-cleaned pintos will usually sell on the market within a cent of the price asked for hand-picked navies. The actual net return on pintos will usually be higher than for navies, because the cost of cleaning is not so great and the rejections under good market conditions are a great deal less.

In abnormal years, like 1916, buyers will take almost any kind of a bean, but even in 1916 buyers were paying a premium for uniform lots of clean, well-graded pintos. In some localities pintos are handled in bulk. Where this is true a uniform grade and cleanness should prevail in the bulk delivered. Many bean markets, however, require that the beans be bagged for shipment. Where such is the case, the beans should be thoroly cleaned and graded. Uniform, standard quality should be bagged in bags of uniform size and marking. The marking suggested is "100 Pounds Colorado Pintos". The remaining marking can specify the grower and address when so desired.

Growers will be able to receive much better prices where a uniform product is produced and where the entire neighborhood is growing one kind of bean. This is due to the fact that the marketing costs are lower under such conditions.

With the exception of one season, Colorado pintos have netted the growers around 4 to 4½ cents for the past eight or ten years. In 1916, prices much higher than this prevailed. But 1916 prices were as abnormally high as 1912 prices were abnormally low. At 4c a pound to the grower, pintos constitute a reliable cash crop which will return good acre net profits to the grower.

The red Mexicans, the spotted Indian beans and teparies do not have a standard market in this section. They are grown extensively in the Southwest. In fact, the pink bean in southern California, Arizona and New Mexico is quite generally grown and is perhaps the most common bean on the market, but for those sections to which Colorado normally ships, namely, the South and East, pintos and navies are the types known. Navy beans may be successfully grown under Colorado conditions, but they require much more hand work and care. Consequently, they are much more expensive to produce. While they bring higher prices on the market, the spread between navies and

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pintos is usually not over one cent. This spread will be more than obliterated by the increased cost of preparing navies for market. Besides, there will be a very much lower rejection in grading and cleaning from pintos than from navies, so that a greater proportion of the crop will actually reach the market.

Market grades have been established for the pinto beans. These grades have been adopted by the bean buyers' associations. It is quite probable that the Bureau of Markets may standardize grades for this crop. When such is done, it will be much easier for growers to prepare a standard product for the market. A standard product can be marketed to a better advantage than an unstandardized product, because very much less inspection is required to determine the quality of the product offered, where beans are so standardized and graded as to permit them to be sold on grade and sample without the necessity of sampling each individual bag.

Communities could do much in helping out their market problem by growing uniform quality and following market demands as to package and cleaning.

COST OF PRODUCING BEANS

It is impossible to give exact figures which will really represent the cost of producing beans, as so many factors enter into the cost of production on different farms. On dry land it was found that beans could be raised with as little labor as corn. The average amount of labor, therefore, required to produce an acre, would be equivalent to about 15 man hours per each acre of beans per year, and about 42 horse hours. While the number of horse and man hours necessary to produce an acre of beans will vary greatly with the season and type of soil, the amount of labor put in is fairly constant with a given set of conditions. The price of everything going into production, however, is increasing. Feed is higher. Horse and man labor and machinery are more expensive. In 1915 and 1916 the labor cost of producing a bean crop on dry land was probably between a minimum of $5.00 and a maximum of $11.00 per acre. The same amount of labor applied in 1917 would be a minimum value of around $12.00 per acre and a maximum of around $25.00 per acre for dry land conditions. To this labor cost it is necessary to add interest and depreciation on machinery and equipment and interest on the land or land rentals.

The cost of producing beans under irrigation will give a labor cost somewhat higher with additional expense for machinery, land rentals, watering expense and other incidental items.

For the years 1914 and 1915 studies were made on the dry lands. These studies showed that at that time the cost of field operations

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for the production of beans varied from a minimum of about $2.25 per acre to a maximum of about $8.00 per acre. Under the same conditions of operation these costs would have been more than doubled in 1917. Under present (1918) conditions it is impossible to make very accurate estimates as to cost of production because of the uncertainty of labor and machinery prices.

USE OF BEAN STRAW

The bean straw and hulls after the beans have been thrashed out will yield from one-half to three-quarters of a ton per acre on dry lands and somewhat heavier yields will be received from irrigated lands. This bean straw is capable of utilization. Especially on the dry lands every bit of bean straw should be saved and fed. Enough experience has already been obtained to indicate that on the dry lands if bean straw is fed with silage that it will return a food value nearly as great as alfalfa. If the bean straw is fed with other dry feeds, it is not as valuable as alfalfa. In fact, it appears to return about one-half the feeding value if fed with dry feeds, and almost as much as alfalfa when fed with succulent feeds. The utilization of bean straw, therefore, constitutes a very material addition to the feed supply under dry land conditions. It will pay growers having any considerable acreage to purchase hand cleaners and clean their beans at home, thus saving the culls, splits, etc. for use as feed upon the farm. Good split beans have a market at about half the price of first grade, first quality products. Splits may even be utilized for sale if properly handled where there is not sufficient stock to utilize them as feed.

BEANS IN ROTATION

Under irrigated conditions, beans furnish an opportunity for a cultivated cash crop, which is their chief value in irrigated rotations. Some types of weed pests can only be cleaned up where a cultivated crop can be introduced. Beans furnish such a crop, which may not only be cultivated, but hoed. On the dry lands, however, beans have a still greater value, because they furnish a cash cultivated crop well adapted for dry lands and capable of returning very good money values, dry-land possibilities considered. It has been found by experience that wheat, after a bean crop which has been well cultivated, will yield as well as after summer tillage or a summer fallow. Since they will usually pay well for growing, beans may be produced on lands which in many cases would be without a crop.

On the dry lands beans have a tendency to build up the soil. If the bean straw is fed to livestock and the manure properly applied to the land, the beans will be a decided, positive asset. If bean growing is a part of the regular farming system, the beans themselves should be grown in rotation. There are many bean diseases which tend to

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not only reduce the yield of beans, but to reduce their salability. One of the best methods of fighting these diseases is to plant beans in rotation, that is, never plant beans two years in succession upon the same land. At least two or three years should intervene in order that the land may not become inoculated with the diseases which affect the bean crop.

IMPROVEMENT OF PINTO BEANS BY SELECTION

The greater proportion of the planting of pinto beans has been done with little or no seed selection. Sufficient experimental work has been done to show that as much progress may be made from selection with pinto beans as is sometimes done with corn in the corn belt. The bean plants are mostly self-fertilized, thus, if a good strain is once obtained, no further selection within the strain is necessary, because the strain is a pure line and breeds true. Every pinto bean grower who is making a business of bean production should start a seed patch. The start should be made by selecting plants in the field. In making selection, the following points should be watched for:

A desirable type of plant—dry land Pinto Bean

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1. High individual plant yield
2. Early maturity
3. Uniform ripening of pods on the plant
4. Freedom from disease

To make a seed plat, the seed of each of these selected bean plants should be planted by itself in a row. These rows are really comparative tests of the value of the selections. The high-yielding rows which are produced represent the mother plants which it is desirable to keep. All the seed from high-yielding rows having other desirable characteristics should be saved. If one strain should prove to be very much better than all others, this should be saved for seed and increased to the fullest extent possible. In this way the entire bean acreage will soon be planted from this high-yielding, early-maturing, even-ripening, disease-free strain.

Preliminary work with bean selection shows that it is easily possible to increase the yield 25 per cent by selection alone. To increase the yield this much would pay for all of the extra work of starting a seed patch and testing out in comparative tests the various selections, thus enabling the grower to pick out the highest yielding strain of his crop from which he may eventually plant his entire crop. It will pay to hand select seed to get seed of uniform marking, uniform size and freedom from disease, even if time and conditions do not permit the better work of the selection of pure, high-yielding strains.

A good field of dry-land pinto beans ready for harvest

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DISEASES OF BEANS

By WALTER G. SACKETT

As mentioned elsewhere. the growing of beans in Colorado for seed purposes is one phase of the industry which has developed at a remarkably rapid rate, considering the length of time that the crop has been raised with this in view. In all probability, one reason for this has been the desire on the part of the seedsmen to obtain seed grown under conditions which normally tend to reduce the percentage of diseased seed. Such conditions obtain to a greater or less extent in both the dry land and the irrigated sections of the State. The absence of moisture in the form of rain, which tends to spread disease over the plants and from plant to plant, together with abundant sunshine are both valuable assets to the localities where beans are being grown.

Another consideration which made Colorado a desirable place for raising seed beans was the fact that until two years ago the disease question was practically negligible. There was plenty of disease-free land, new so far as bean culture was concerned, on which there was good reason to believe that no difficulty would be experienced for years to come in the line of plant diseases. But the inevitable has happened, and in the remarkably short space of two years.

Someone innocently planted diseased seed from which unhealthy plants developed, and from these as a starting point, it has been a relatively simple matter for the infection to spread from vine to vine, plant to soil, and field to field.

Where irrigation is practiced, the irrigating water, flowing as it does thru infected fields, carrying more or less trash and diseased soil with it, cannot be lost sight of as a means of disseminating the various ailments to which the bean is heir.

Our severe and prolonged winds which may assume the form of sand storms, transport quantities of soil, irrespective of whether it is diseased or not, from one locality to another. The mechanical injury to the pods and beans which results from this incessant pounding by the sand grains, not only weakens the plant. but also opens up the way for subsequent infection with germ-laden soil particles.

Some growers have failed to use beans in a rotation and have planted beans after beans on the same land, having lost sight of the fact that, aside from this being poor farm practice, the dangers from disease are increased very greatly by such a procedure.

Little if any attention has been given either to the planting or the selecting of disease-free seed, with the result that we have built up a big seed business in a phenomenally short time, but a business which is destined to fail, as has been the history elsewhere, unless we

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can establish a reputation for our seed with respect to quality, purity and freedom from disease.

Now is the time to do this, before our fields become generally infected, and while the prevalence of disease is so slight that it can be controlled for the most part by the means that we have at our disposal.

For the present consideration, we shall confine the discussion of bean diseases to those which have been observed to occur in the State during the last two years, and which, if neglected, may prove a serious menace to the industry.

Fig. 1.—Bean pods affected with Bacteriosis or Bacterial Spot

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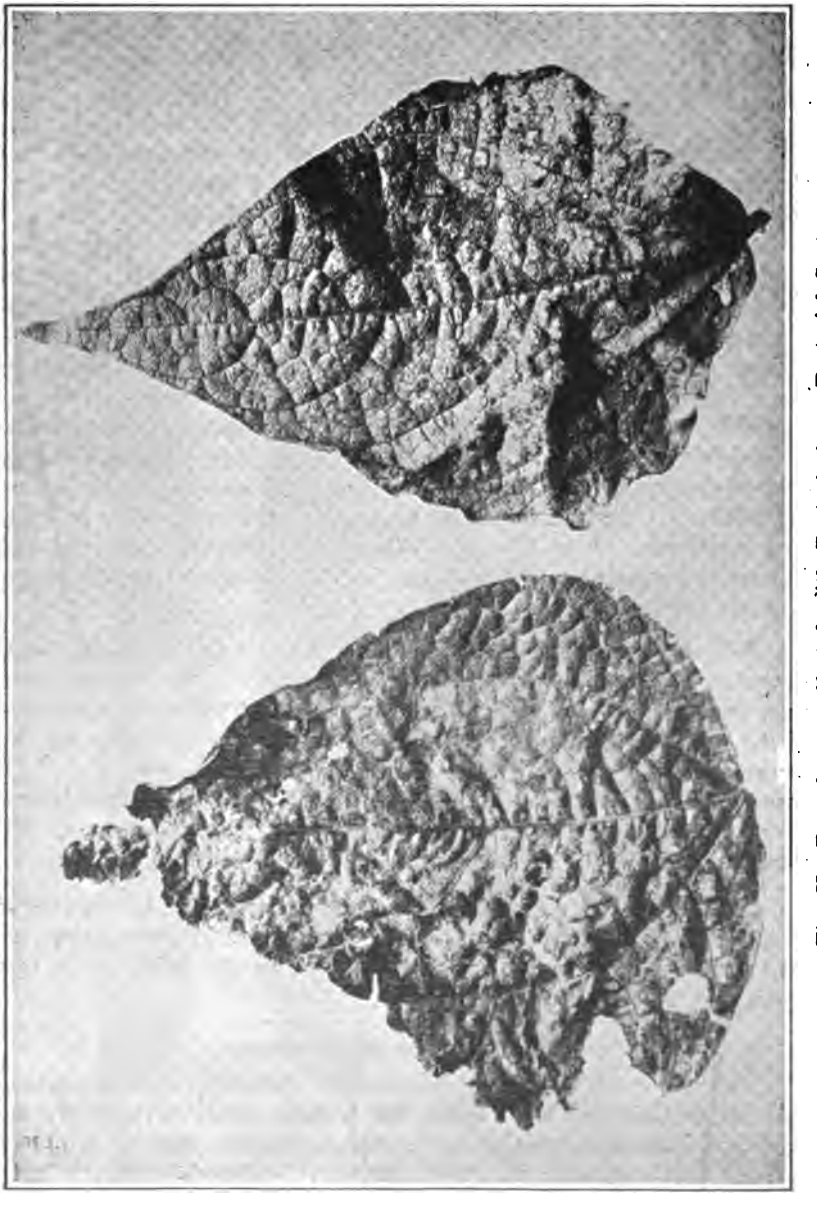

Fig. II.—Bean leaves affected with Bacteriosis or Bacterial Spot

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DESCRIPTION OF DISEASES

Bacteriosis or Bacterial Blight

Without doubt, the greatest damage to our bean crop during 1916 resulted from an attack of the bacterial blight. This is caused by a germ, *Pseudomonas pheseoli*, which enters the plants thru the breathing pores or stomata and thru wounds produced by mechanical injury.

The disease is common upon field, garden and lima beans and attacks leaves, pods, stems and seed. It is very conspicuous upon the pods and leaves and can be recognized most easily, perhaps, upon the former, particularly in the wax varieties. Here we find watery spots ranging in size from tiny specks to areas three-eighths of an inch and more in diameter. They are usually irregular in outline and roughly circular in shape. On the wax varieties, the spots are translucent or watery, amber-yellow in color and frequently have a rosy-red margin. Their appearance, on the whole, is not unlike an ordinary blister, except that they are neither raised nor sunken. In the more advanced stages, they may be coated over with a thin, pale yellow or amber-colored crust which is composed largely of the bacteria which produce the disease. Ulcers in all stages of development can usually be found on a single pod. (See Fig. I.) When the lesions are numerous, they frequently coalesce, or run together, so that the whole side of the pod presents one continuous canker.

The injury to the leaves is very marked. In the early stages, irregular, watery spots can be found scattered over the surface which soon turn yellow and in a short time become frosty-brown in color. If the spots are numerous they will often coalesce and give the dry, brown leaf a peculiar blistered appearance. (See Fig. II.) The tissue in this condition is extremely brittle and is easily torn and broken, which accounts for the ragged condition of blighted leaves. The stems are affected in much the same way as the foliage.

Badly diseased plants lose their leaves early and fail to mature their seed. Spotted pods are unfit for the market as green beans, and seed from them is very apt to be diseased as the infection is communicated to the seed from the pod.

Pod-Spot or Anthracnose

Pod-spot or Anthrocnose has been of relatively little importance thus far in Colorado bean fields, but because of its ravages in other localities, it seems advisable to become acquainted with its symptoms in order that it may be recognized should it become serious.

The disease makes its first appearance on the seed-leaves and stems of the seedling plants. It manifests its presence there by brown, discolored, sunken spots or ulcers, indicating rather clearly that

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the causal fungus, *Colletotrichum lindemuthianum*, has been carried over winter in the seed.

In due course of time, spores, by means of which the disease is spread, are produced in these early spots. Eventually they are blown, or otherwise carried, to the growing stems, leaves and pods, where they soon become established and begin their destruction.

Fig. III.—Bean pods affected with Anthracnose or Pod Spot (After Whetzel, Bulletin 255, Cornell Experiment Station)

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On the leaves we find reddish or blackened areas developing along the large veins on the under surface. The veins may be eaten thru by the fungus and destroyed, while the blade shows numerous cracks or holes with shriveled, blackened margins. Leaves in this condition are practically worthless as food-building organs, and as a result the nutrition of the plant is greatly impaired; either the yield of seed is reduced appreciably or the seed fails to mature.

Previous to the time of blossoming, the attack has been concentrated against the leaves, and by the time the young pods make their appearance the fungus has become well established and is amply supplied with spores. These soon find their way to the young, tender pods where they produce rusty-brown or black sunken spots with reddish or yellowish margins. (See Fig. III.) These vary in size, much as the bacterial spots previously described. The spores of the fungus are produced in the center of the black ulcers and form little pink masses visible to the naked eye. They are glued together with a mucilaginous material which sticks them securely to the spot. However, as soon as a drop of moisture touches them, the mucilage is dissolved and the spores are set free in the water. At this time any disturbance of the plant is apt to scatter the spores in the flying drop of water, and for this reason beans affected with anthracnose should never be cultivated while the dew is on them or while they are wet from a shower.

From the affected pods, the disease finds its way to the seed where it produces the familiar rusty-red or brown spots. In severe cases, the whole seed may be involved, altho ordinarily only a slight discoloration is produced on one side.

Bean Rust

Bean rust was observed in several fields last year, but it came so late in the season that little if any damage resulted. The causal fungus, *Uromyces appendiculatus,* attacks the leaves, stems and pods. The rust, as the name implies, can be recognized in its summer stage by the small, raised, rusty-brown powdery specks on the under side of the leaf which rub off easily with the fingers as a rusty-brown powder.

In the winter stage, the specks are black in color and occur on both surfaces of the leaf. When found on the upper side, they are usually surrounded by a light border, apparently where the green leaf tissue has been killed. (See Fig. IV.) While the rust is not uncommon, it has rarely been of sufficient economic importance to cause any considerable alarm. Of course, if the attack should come early in the season and be very general, the crop would suffer in proportion as

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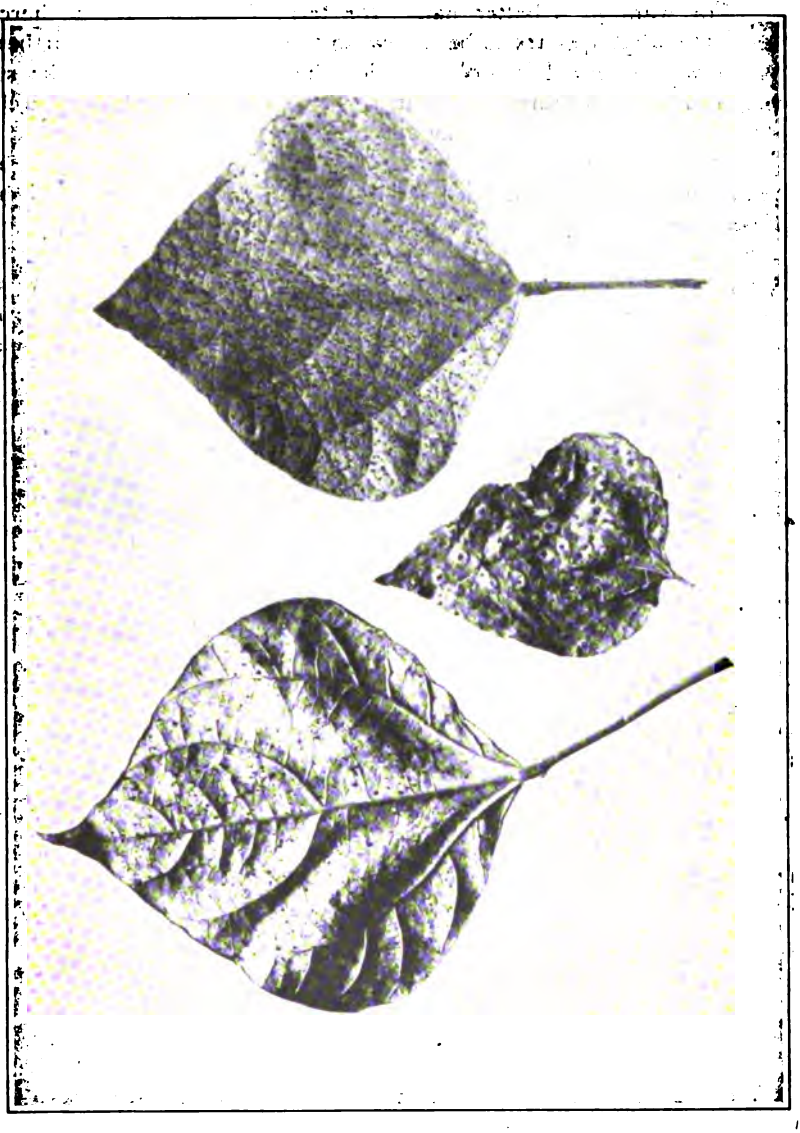

Fig. IV.—Bean leaves affected with Rust

the vitality of the plant was affected. As the disease winters over on the leaves, the destruction of these by burning offers the best means of eradication.

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Bean "Streak"

For want of a better name, the term "Streak" is used here to designate what appears to be a new and undescribed disease of beans, which was observed in Colorado for the first time during the summer of 1916. Whether this is in reality something new, or merely a different manifestation of an old trouble, remains to be seen. It attacks stems, leaves and pods, the symptoms on the first two of these being much the same as with the bacterial blight. On the pods there appear peculiar rusty or orange-brown discolorations in the form of irregular splotches, just as if a brown stain had been spattered on them, and had run down in lines or streaks. (See Fig. V.) The side of the pod next to the plant is practically free from the discoloration, while the outer side may be more or less affected over its entire sur-

Fig. V.—Bean pods affected with "Streak"

face. The leaves are destroyed and the plants become defoliated before the crop matures.

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It is our purpose to make a study of this disease during the coming summer and to determine, if possible, its cause and control.

Fig. VI.—Bean plant affected with "Streak". (By courtesy of Dr. H. G. McMillan.)

MEASURES OF CONTROL

The measures of control which can be recommended for any one of the diseases described, apply equally well to all. Accordingly, this phase of the question has not been taken up in connection with the individual diseases, but has been reserved for consideration as a whole.

1. Plant beans on the same land not oftener than once in three or four years, particularly if disease has been prevalent. Solls which once become thoroly infected as a result of continuous cropping are seldom safe to use for the same or closely related crops for years to come.

2. Wherever practical, destroy all diseased vines and trash by burning.

3. If the bean straw from diseased vines is to be fed, do not use the manure on a field that is to be planted to beans.

4. As far as possible, avoid cultivating the beans early in the morning when there is dew on them, or when they are wet with rain.

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5. Hand pick disease-free pods, or if possible, select disease-free plants, for seed. Use these to plant a seed plat on land which has never raised beans and which is removed some distance from the main crop.

Remember that hand picking of seed as it comes from the flail or thrasher for the purpose of controlling disease is of no value, since it is impossible to detect even a small percentage of diseased seed.

6. Seed treatment for beans is of no practical value since any chemical that would penetrate the seed deeply enough to destroy the disease-producing organism would likewise be apt to kill the seed.

7. Spraying with Bordeaux mixture, 5-4-50 formula, even when done thoroly by competent persons, is at best unsatisfactory, unprofitable and only partially successful. However, if one desires to try this, the first application should be made when the plants have their first set of true leaves, repeated ten days later, and again just after blossoming. Remember that if any real benefit is to be derived, the stems, leaves and pods must be kept covered with the spray material.

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RECLAIMING NITRE SOIL IN THE GRAND VALLEY

By
E. P. SANDSTEN

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Fig. 1. Method of reclaiming nitre land by flooding

Fig. 2. Furrow method of reclaiming nitre land

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RECLAIMING NITRE SOIL IN THE GRAND VALLEY

By E. P. SANDSTEN

The experimental work of Dr. Headden and Professor Sackett* of this Station has proven conclusively that the origin of nitre, often called black alkali, so abundant in many of our Colorado soils, is due to the activity of the nitre-forming organisms. The nitre is not confined to any particular section of the State, but occurs in almost every district and in all types of soil.

A study of soil management, especially in the orchard areas of the Grand Valley, has led the writer to conclude that the excessive accumulation of nitre is greatly increased by clean cultivation, as extensively practiced by the fruit growers.

It is a well-known fact that in most semi-arid soils there is little or no fermentation of organic materials, due to the action of prolonged sunshine, light rainfall and dry atmosphere. This, coupled with the presence of a high percentage of alkaline salts, forms ideal conditions for the activities of the nitre-forming organisms. The additional fact that nitre rarely occurs in injurious quantities in soils on which alfalfa is grown continuously for a long series of years, would indicate that land kept constantly in clean culture furnishes the best conditions for the nitre-forming organisms.

The orchard survey of Grand Valley, made by the Horticultural Department, reveals the fact that more than one thousand acres of bearing orchards, and orchards just coming into bearing, have been destroyed by nitre during the last few years, and, in addition, a considerable portion of the remaining orchards in the Valley are showing signs of nitre poisoning.

These observations led the writer to undertake some work in Grand Valley to reclaim land that had become barren because of excessive nitre, and also to check the process of nitre-formation in orchards that were still healthy and productive, but which showed signs of nitre poisoning.

The presence of excessive nitre in the soil is readily distinguished by the characteristic reddish-brown discoloration, and the mealy or powdery texture which always accompanies this trouble.

In the orchards, the presence of nitre is also readily distinguished by the appearance of the foliage of the trees, especially the foliage on tender growing shoots. The margins of the leaves

*See Bulletins Nos. 155, 160, 178, 179, 184, 186, 193.

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turn reddish-brown, while the central portion assumes a pale yellow, greenish color. When the nitre is present in large quantities, the whole leaf turns reddish brown, and, in severe cases, the nitre may even attack the branches and the whole tree. In many instances, only a portion of the tree is affected. This is due to the fact that nitre may be present only in small spots, and the roots, feeding in these, become poisoned, and the branches which receive food from the roots in these areas show the presence of the poison. Often, a half tree will die, while the remainder of the tree appears to be perfectly healthy.

Several thousand acres of land in Grand Valley that have been made unproductive by nitre poisoning, could have been saved, and could yet be saved if the growers practiced rational methods of soil management.

The object of this investigation was to determine the quickest and most economical method of correcting and reclaiming nitre land in the Grand Valley. Particular attention was paid to land occupied by fruit trees, or lands that had been occupied by fruit trees which had been killed by excessive nitre in the soil.

The work was started in June, 1914, and has been carried on for the last three seasons on a farm west of Grand Junction.

Arrangements were made to take over two acres of land on which an apple orchard had been killed and the trees removed several years previous. This piece of land, at the beginning of the experiment, was entirely barren of vegetation. Even the hardiest and most resistant weeds failed to grow on it. Samples of the soil analyzed by Dr. Headden, Station Chemist, showed excessive amounts of nitrates. The condition of barrenness had existed for several years without any apparent change in the character of the soil, so far as sustaining plant life was concerned. The water table of this plat of land during the irrigating season came to about four feet of the surface and in no way interfered with the growth or ripening of the ordinary farm crops. The land is nearly level, but with a slight fall toward the south. The soil is heavy and does not permit the water to percolate freely.

METHODS EMPLOYED

The land was well plowed, harrowed and prepared in the usual manner for seeding grain crops. A portion of the land, about one-fourth acre, running the whole length of the field, was enclosed with an embankment of earth, and water was led into this enclosure so that the whole strip was covered to the depth of several inches. The land was kept covered for ten days, permitting the water to gradually work its way thru the soil and drain off

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slowly. After the water had been taken off and the embankment leveled down, the strip was seeded to oats. A fine stand of oats was obtained without any further work on the land. (See Fig. 1.)

This strip has now borne full crops for the last three seasons, and shows no indication of returning to its former condition. No crop has been taken off the land, but each has been plowed under.

The balance of the land was seeded to oats, rye, rape, sorghum and winter vetch. After seeding, the land was corrugated, the furrows were placed close together to obtain the maximum of exposure, and then water was permitted to run in these furrows for thirty-six hours. (See Fig. 2.) The seed started to grow along the edges of the water, especially the oats and rye, but the ridges remained barren. The irrigation was continued at intervals of several days during the first season. The results obtained showed that a certain amount of the nitrates had been washed out by irrigation. However, the ridges remained barren and showed the characteristic brown color and powdery texture. At the end of the season the field was almost as barren as before. The rape, sorghum and winter vetch made a poorer showing than the oats and the rye, and were discarded as unsuited for the work.

The corrugating method of washing the soil was continued during the last two summers, with the oats and rye as crops, and the field is now practically reclaimed, tho there are isolated spots which are still more or less barren. The crops on the reclaimed portions were very rank and dark green in color and showed that a large amount of nitrates was still present in the soil. (See Fig. 3.)

Fig. 3. A crop of rye on reclaimed land

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FLOODING GIVES QUICKEST RESULTS

There are two conclusions which we can draw from this work. First, that the quickest way of reclaiming nitre land is by flooding. Second, that the corrugating method, while beneficial, is too slow, and, in the long run, more expensive than the flooding method. Lands that are in the first stages of nitre poisoning may be restored by using the corrugating system of irrigation, but on land made unproductive by excessive nitre, and especially if the character of the soil and the lay of the land are such as to permit of rapid drainage, and where rapid, complete reclamation is desired, the flooding method is recommended.

COVER CROPS HELP CHECK NITRE IN BEARING ORCHARDS

At the same time that the work of reclaiming this particular piece of land was undertaken, experiments were carried on to correct the nitre condition of soils in bearing orchards, by the use of cover crops. This method of soil treatment is particularly applicable to orchards, and since most of the orchard land is deficient in vegetable matter, due principally to clean cultivation, the plowing under of cover crops is the cheapest and most effective means of supplying this deficiency, and at the same time checking the tendency to form nitre.

Two orchards in the first stages of nitre trouble were selected and were seeded to hairy vetch. The seeding was done early in September, and the plants made a rather poor showing during the fall. The poor stand was due to three causes: First, the lack of water; second, to the dense shade caused by the apple trees; and, third, to the tramping of the land in harvesting the fruit.

In spite of these drawbacks, the vetch showed up well the following spring, particularly in one of the orchards, where it completely covered the ground and attained a height of over 5 feet. (See Fig. 4.)

The vetch was plowed under during the second week in June, when it was in full bloom. Both of these orchards were in the first stages of nitre trouble, and to all appearances, the trouble was checked.

In plowing under large green crops in the orchard, there is some danger of too rapid fermentation and heating which may cause injury to the trees. This generally happens if the plowing under is delayed until the latter part of June, or until July. For this reason, the plowing under of large green crops should be done as early as possible.

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Fig 4. A cover crop of hairy vetch in a Grand Valley orchard

CLEAN CULTIVATION RESPONSIBLE FOR PRESENCE OF NITRE

As indicated above, the presence of excessive nitre in so many of the orchards in Grand Valley, is in the main, due to the prevailing system of soil culture. It has been a universal custom in the Valley, up to within a few years ago, to practice clean cultivation in the orchards, and this practice seems to have given the best results. The clean culture method is advisable only so long as the soil conditions remain favorable to tree growth and fruit production, and when these show signs of decline, corrective measures must be taken. The corrective remedy lies in the use of cover crops, alternating with clean culture. The use of cover crops is now more extensively practiced in the Grand Valley orchards, and with its more extended use, we shall look for less nitre poisoning.

DRAINAGE IMPORTANT

In connection with the reclamation of nitre land, it should be borne in mind that drainage is of vital importance. If irrigating waters percolating thru the soil have a means of escaping readily, the nitre salts will be carried off by them, as they are very soluble. Lack of proper drainage makes evaporation the only source by which water is eliminated from the land, and this is sure to cause

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trouble, as the salts remain in the soil after the water has evaporated. If proper drainage is provided, the salts, to a large extent, will be carried off in the waters thru the subsoil and into the drainage.

The nitre trouble is only one of the problems which confront the land owners; another and equally important one is seepage. Cheap and abundant irrigation water have led to over-irrigation. This, togeher with the natural seepage from canals and laterals has filled up the subsoil with water and brought the alkaline salts to the surface. In many instances the water table is within 4 feet of the surface, and on some of the lower land the water reaches the surface. Where these conditions exist, drainage is the only remedy. The occurrence of nitre in the soils of the Grand Valley and other sections of the State, has little or no relation to drainage but is a distinct and separate problem.

While the apple tree roots, in most cases, do not extend deeper than 4 or 5 feet, (practically all the feeding roots are confined to the upper 3 feet of soil), capillary action carries the water too close to the feeding roots and interferes with the proper drainage and aeration of the soil in the feeding zone. Further, the high water table usually occurs during the growing season, and thus directly affects the growth of the trees. A high water table is less harmful during the winter months when the trees are dormant.

The importance of good drainage and the use of cover crops in connection with orchard operations should be known by every fruit grower in the Valley.

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